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86th Congress, 2d Session - - - - - - House Report No. 2226

PANEL ON SCIENCE AND TECHNOLOGY SECOND MEETING

REPORT

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SIXTH CONGRESS

SECOND SESSION

PURSUANT TO

H. Res. 133

[Serial j]

SEPTEMBER 27, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

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COMMITTEE ON SCIENCE AND ASTRONAUTICS

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., July 11, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: I am forwarding herewith for committee consideration a report, "Panel on Science and Technology—Second Meeting," assembled and edited by Dr. Charles S. Sheldon II, technical director, who has also taken principal staff responsibility for the substantive work of the panel in its meetings this year.

By invitation of the chairman of the committee, the panel members were assembled to present papers either on particular areas of science, with attention to the needs of these disciplines, or on general problems of public policy in relation to science and technology. The results of the 2-day meetings were of such interest that this report has been prepared to trace the actions following the first meeting already reported, the proceedings of the second meetings, and subsequent correspondence.

The committee appreciates the continuing effort and cooperation provided by members of the panel in their work with the committee.

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., September 27, 1960.

Hon. SAM RAYBURN,
Speaker of the House of Representatives,
Washington, D.C.

DEAR MR. SPEAKER: By direction of the Committee on Science and Astronautics, I submit the following report for the consideration of the 86th Congress.

OVERTON BROOKS, *Chairman.*

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Union Calendar No. 1012

86TH CONGRESS, 2d Session } HOUSE OF REPRESENTATIVES { REPORT No. 2226

PANEL ON SCIENCE AND TECHNOLOGY—SECOND MEETING

SEPTEMBER 27, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BROOKS of Louisiana, from the Committee on Science and Astronautics, submitted the following

REPORT

[Pursuant to H. Res. 133.]

PANEL ON SCIENCE AND TECHNOLOGY
SECOND MEETING

Introduction

The report on the first meeting of the Panel on Science and Technology with the Committee on Science and Astronautics traced the origin of the idea to conduct such gatherings from time to time when members of the committee could meet both in formal and informal sessions with representative scientists to exchange views on public policy aspects of science and technology. It was recognized in that report that such frank exchanges offered a useful supplement to the normal hearings conducted by the committee. The first meeting, held March 25, 1960, bore this out. At that time, it was announced that there were planned 2 days of meetings to be scheduled sometime before the end of the current session of the Congress. In accordance with that plan, the panel was called to Washington for June 2 and 3, 1960, and the record of events in this connection follows:

Letters for Second Meeting of the Panel

The following letter of invitation to the second meeting of the panel was sent to all panel members:

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C., April 22, 1960.

Dear ——— ———: As I indicated in my letter of April 7, to you, the committee wanted to schedule a second round of formal meetings with the Panel on Science and Technology in May before Congress becomes involved in the adjournment rush and many of our panelists have commencement and summer obligations. We are going to miss this goal by a week.

The suggestion has been made that all the panelists be polled as to alternative meeting dates. (I recognize that we were extremely fortunate to have managed last time to have 11 out of 14 present.) However, our schedule is so tight here, that I can only hope that a single set of dates will still be able to draw a fair representation. These dates are Thursday and Friday, June 2 and 3. If you will be able to come, please let me know. The financial arrangement will be as it was before—the consultant fee for the 2 days here, plus transportation when it is reported to us.

The papers presented last time were of great interest to us, and we hope for a larger number now that the way has been shown. I should

like to suggest that either of the following two topics would be quite suitable: (*a*) developments, importance, and needs to be expected in an area of scientific or technical specialization in the next 10 years or so, with recommendations for action; or (*b*) elaboration or development on some of the specific problems of setting priorities, managing research, providing support, and related matters as discussed on an impromptu basis at the last session.

We plan to have our sessions from 10 to 12 or so on each of the 2 days, meeting in our regular committee room, 214–B, New House Office Building. There should be time for 15-minute summaries of three papers each day. This would still allow time for some discussion. We hope there will be more than six papers prepared, and all of these will be published in the record of the meetings. One of the days we will reserve a period for closed-door, off-the-record observations. Undoubtedly, longer talks on this basis can be arranged individually. Comments and suggestions on any pertinent matter will be welcomed.

If you will let me know whether you plan to prepare a paper, and whether you would consider giving us an oral summary of it, I should appreciate it very much. Also, any suggestions, questions for discussion, or other information which you believe would be helpful for us to have in advance would be much appreciated.

I hope to see you in June at the meetings.

With all good wishes, I am,

Sincerely yours,

OVERTON BROOKS, *Chairman.*

LETTERS OF REPLY FROM PANEL MEMBERS

The following letters of reply were received from members of the Panel on Science and Technology (in addition, Dr. Thomas F. Malone replied by telephone, accepting the invitation from Chairman Brooks):

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Cambridge, Mass., April 26, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: Thank you for your letter of April 22 outlining the plans for the meeting of the Panel on Science and Technology on June 2 and 3. I am planning to attend this meeting, although I will arrive late on the first day, since I have a long-standing commitment to lecture at the U.S. Military Academy at West Point on the morning of June 2.

I will be glad to prepare a paper and would be willing to give a 15-minute oral summary of this at the time of the meeting. The details on this paper I will submit to you later.

I look forward to the second meeting of the panel.

Sincerely yours,

H. GUYFORD STEVER.

SOUTHWEST RESEARCH INSTITUTE,
OFFICE OF THE PRESIDENT,
San Antonio, Tex., April 26, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

MY DEAR CONGRESSMAN BROOKS: Let me first thank you most sincerely for the photographs you sent on April 21. They are a pleasant reminder of a most memorable meeting with you and the other members of the committee.

In regard to the forthcoming meeting on June 2 and 3, I will be most happy indeed to attend. The topics you have chosen for special attention should most certainly result in valuable and stimulating discussion.

Since I have already presented some formal remarks to the committee, I believe it would be best if I defer on this occasion to the other members of the panel. However, I do have certain thoughts which I would like to bring to the attention of the committee, and I shall look forward to doing this during the general discussion.

In particular, I have the feeling that somewhat of a vacuum exists in our research leadership today. Traditional thinking, to my mind, is in many cases preventing the establishment of new types of research organizations, badly needed for our overall national effort. Some of these matters were touched on glancingly in the paper I presented at our last meeting.

I would very much like to exchange views on this subject with the committee members.

I am looking forward to seeing you early next month. Until then, my sincerest personal regards.

Very truly yours,

MARTIN GOLAND.

THE UNIVERSITY OF CHICAGO,
DEPARTMENT OF METEOROLOGY,
Chicago, Ill., April 26, 1960.

Dr. CHARLES S. SHELDON II,
Technical Director, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR DR. SHELDON: With reference to your letter of April 23, I regret to inform you that it will not be possible for me to attend the meeting of the Science Advisory Panel on June 2 and 3. I have an engagement of long standing to visit several universities in South America, and it is not possible for me now to change this engagement.

Yours sincerely,

SVERRE PETTERSSEN.

CALIFORNIA INSTITUTE OF TECHNOLOGY,
OFFICE OF THE PRESIDENT,
Pasadena, Calif., April 29, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

MY DEAR MR. BROOKS: I am exceedingly sorry that scheduled commitments here in Pasadena will prevent my coming to Washington on June 2 and 3 to attend the meetings of your Panel on Science and Technology. This is a very regrettable conflict and I am sorry not to be able to be with you again.

Sincerely,

L. A. DUBRIDGE.

THE UNIVERSITY OF ROCHESTER,
COLLEGE OF ARTS AND SCIENCE,
DEPARTMENT OF CHEMISTRY,
Rochester, N.Y., April 29, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR SIR: I have your letter of April 23, 1960, about the proposed meeting on June 2 and 3 of the Panel on Science and Technology.

On May 19 I will leave for a rapid trip to U.S.S.R. from which I should return on May 30. If I return on schedule, I will be happy to attend the meeting in Washington. With this reservation you may count on me.

Very sincerely yours,

W. ALBERT NOYES, Jr.

THE UNIVERSITY OF BUFFALO,
OFFICE OF THE CHANCELLOR,
Buffalo, N.Y., April 29, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: Answering your letter of April 22, I will be pleased to accept your invitation to appear before your Committee on Science and Astronautics. You mentioned 2 days, June 2 and 3, as possible dates. Unfortunately, I have to be in Buffalo on June 2, but would be able to appear on June 3. Please let me know if I should make it definite.

Sincerely yours,

C. C. FURNAS, *Chancellor.*

LOUSIANA STATE UNIVERSITY,
THE GRADUATE SCHOOL,
OFFICE OF THE DEAN,
Baton Rouge, La., April 30, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: I plan to attend the Panel on Science and Technology meeting of June 2 and 3.

At that meeting I would like to present orally a paper on recent developments and needs in the field of geology. I believe that this type of background information will be useful to your committee. I have clearance which will enable me to present the views of the Section of Geology of the National Academy of Sciences as they evolved during a 2½-day session which was concerned with desirable trends in geological research.

It will be necessary for me to take an afternoon flight on the 3d, as the following day is commencement at LSU.

Sincerely,

RICHARD J. RUSSELL.

PURDUE UNIVERSITY,
SCHOOL OF MECHANICAL ENGINEERING,
Lafayette, Ind., May 2, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR CONGRESSMAN BROOKS: This is to inform you that I am planning to attend the next meeting of the Panel on Science and Technology on June 2 and June 3. I will let you know at a later date before the meeting whether or not I will prepare a paper for the meeting. It so happens that this is the closing of our school semester, and I am rather short of time.

Looking forward to seeing you at the June meetings and with kindest personal regards, I am

Sincerely yours,

M. J. ZUCROW,
Atkins Professor of Engineering.

MAYO CLINIC,
SECTION OF BIOPHYSICS,
Rochester, Minn., May 5, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

MY DEAR MR. BROOKS: I have received your letter in which you state that a second round of formal meetings of the Panel on Science and Technology will take place on Thursday and Friday, June 2 and 3.

Although I hope I shall be able to attend this meeting, due to previous commitments I will not be in a position to prepare and present a 15-minute summary of papers that you are anticipating from at least six members of the panel.

I enjoyed very much the first meeting of the panel and look forward with anticipation to future meetings.

Sincerely yours,

E. J. BALDES,
Senior Consultant in Biophysics.

SMITHSONIAN INSTITUTION,
ASTROPHYSICAL OBSERVATORY,
OFFICE OF THE DIRECTOR,
Cambridge, Mass., May 6, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: The dates of Thursday and Friday, June 2 and 3, are available for me to attend the Panel on Science and Technology, advisory to your Committee on Science and Astronautics in the House of Representatives. I hope that I shall have time to develop a short elaboration of the subject on which I commented at the last meeting. This concerns research projects of intermediate magnitude that cannot be properly pigeonholed either with regard to a scientific discipline or the specific objectives of a single supporting agency. I hope to have a few examples of this type of problem. The paper might be entitled "A Special Problem in Research Financing."

The type of program you outline sounds extremely interesting and valuable, and I anticipate with much pleasure further association with your committee and its panel.

Sincerely yours,

FRED L. WHIPPLE, *Director.*

THE UNIVERSITY OF CALIFORNIA,
OFFICE OF THE DIRECTOR,
La Jolla, Calif., May 9, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: Thank you very much for your letter about the next meeting of your committee with the Panel on Science and Technology June 2 and 3. I shall be able to attend the session on Thursday, June 2, but have to be in Berkeley, Calif., on Friday, June 3.

If your agenda can be so arranged, I shall be pleased to present a paper on International Cooperation in Oceanography, with particular reference to the proposed International Commission for Surveys of the Ocean and the proposed International Indian Ocean Expedition.

I suggest also that one item on your agenda be the relationship between the Federal Government and universities, and the conduct of basic research and training of scientists, with specific emphasis on the need for development of graduate schools in our universities.

I am greatly looking forward to meeting with your committee.

Very truly yours,

ROGER REVELLE.

THE GENETICS FOUNDATION,
THE UNIVERSITY OF TEXAS,
HUMAN GENETICS RESEARCH,
Austin, Tex., May 11, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. BROOKS: Thanks for your letter of April 23.

If I can arrange my affairs to do so, I will attend the June 2–3 meetings of the Panel on Science and Technology. However, at this time I am doubtful that I can make the meetings. I will notify you if my plans are changed so that I can take part. The panel meetings offer us an excellent opportunity to express our opinions and to learn from other scientists. We should not miss the meetings unless that is unavoidable.

Sincerely,

CLARENCE P. OLIVER,
Professor, Zoology.

STATE UNIVERSITY OF IOWA,
DEPARTMENT OF PHYSICS AND ASTRONOMY,
Iowa City, Iowa, May 25, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR CONGRESSMAN BROOKS: Please be advised of my intention to participate in the second meeting of the Panel on Science and Technology on Thursday and Friday, June 2 and 3. I plan to have a written paper on the topic "Federal Support of University Research in Science".

* * * * * * *

Sincerely yours,

J. A. VAN ALLEN.

PRESS RELEASES ANNOUNCING SECOND PANEL MEETING

The following two press releases were issued by the committee for nationwide coverage. (In addition, appropriate regional announcements were made in the areas where the various panel members live.)

[Release Sunday a.m.'s, May 29, 1960]

COMMITTEE ON SCIENCE AND ASTRONAUTICS
HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

A group of prominent American educators will meet next month in Washington for scientific roundtable discussions with Members of Congress.

The participants are members of a unique Panel on Science and Technology formed by the House Committee on Science and Astronautics to meet with it periodically to explore important scientific and technological problems.

The House group is the only committee in Congress with general jurisdiction over science. As such, it has attempted to keep itself currently informed of advances in the world of science.

Committee Chairman Overton Brooks, Democrat, of Louisiana, announced that the panel will meet with the House group June 2 and 3. Both meetings will be open to the public, with a period during one of the meetings reserved for closed-door, off-the-record discussions.

Panel members who have signified their intention of attending include the following:

Dr. Edward J. Baldes, a senior consultant in biophysics at the Mayo Clinic, Rochester, Minn.;

Dr. Clifford C. Furnas, chancellor of the University of Buffalo. Dr. Furnas is a chemical engineer;

Mr. Martin Goland, president of the Southwest Research Institute, San Antonio, Tex. Mr. Goland is an engineer who specializes in applied mechanics;

Dr. Thomas F. Malone, director of research, the Travelers Insurance Cos., Hartford, Conn. Dr. Malone is a meteorologist;

Dr. Roger Revelle, director of the Scripps Institution of Oceanography, University of California, at La Jolla, Calif.;

Dr. Richard J. Russell, professor of geography, acting dean of the Graduate School, Louisiana State University, Baton Rouge, La.;

Dr. H. Guyford Stever, professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.;

Dr. James A. Van Allen, professor of physics, State University of Iowa, Iowa City, Iowa;

Dr. Fred L. Whipple, director of the Smithsonian Institution's Astrophysical Observatory, Cambridge, Mass.

Dr. Maurice J. Zucrow, Atkins Professor of Engineer, Purdue University, Lafayette, Ind.

Another member of the panel, Dr. W. Albert Noyes, Jr., professor of chemistry, University of Rochester, tentatively accepted the committee's invitation to be present, subject to his returning in time from Moscow, where he is attending a meeting of the International Union of Pure and Applied Chemistry, of which he is president.

In discussing the forthcoming meeting, Congressman Brooks stated:

"This is the second of our meetings with the Panel on Science and Technology. The first was held March 25 and it has been the feeling of the members of the committee and the panel that the results were very worthwhile.

"One reason for the formation of the panel has been to bring together the views and needs of the scientific and technical community of the United States with responsible policymakers of the Congress. It is my hope that as the meetings continue they will prove of great value to both the participants and the country. We hope that out of these discussions will come many worthwhile ideas that will help advance the well-being of this Nation."

The chairman said members of the panel will present formal papers on various scientific and technological problems which they feel are of interest to the Congress and the public.

He stated: "Dr. Revelle, for example, plans to present a paper on international cooperation in the exploration of the ocean's depths. He will address himself particularly to a discussion of the proposed International Commission for Surveys of the Ocean and the proposed International Indian Ocean Expedition.

"Dr. Russell will present a paper on recent developments and needs in the field of geology, while Dr. Whipple plans to discuss research projects of intermediate magnitude which cannot be properly identified either with regard to a scientific discipline or the specific objectives of a single supporting agency. His paper will be entitled, 'A Special Problem in Research Financing.'"

Brooks said he was confident that these and other papers to be presented by the panel members "will undoubtedly prove of great interest and value to the committee and to the public."

[Press announcement, June 1, 1960]

COMMITTEE ON SCIENCE AND ASTRONAUTICS

HOUSE OF REPRESENTATIVES

WASHINGTON, D.C.

Eleven prominent scientists and educators from nine States will meet Thursday and Friday, June 2 and 3, with the House Committee on Science and Astronautics for a discussion of scientific and technological problems.

The meetings will be held in the committee's hearing room at 214–B, New House Office Building. Both sessions will convene at 10 a.m. and will be public.

Some of the scientists and educators, all of whom are members of the Committee's Panel on Science and Technology, will present formal papes on a variety of subjects. Others will discuss more informally various problems of interest to the scientific community and to the Congress.

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Among the participants in the panel discussions will be Prof. J. A. Van Allen of State University of Iowa, whose work helped lead to the discovery of the Van Allen Radiation Belt around the Earth, and Dr. W. Albert Noyes, Jr., of the University of Rochester, who has just returned from Moscow, where he attended a meeting of the International Union of Pure and Applied Chemistry, of which he is president.

The complete list of participants in the panel discussions follows:

Dr. Edward J. Baldes, a senior consultant in biophysics at the Mayo Clinic, Rochester, Minn.;

Dr. Clifford C. Furnas, chancellor of the University of Buffalo. Dr. Furnas is a chemical engineer;

Mr. Martin Goland, president of the Southwest Research Institute, San Antonio, Tex. Mr. Goland is an engineer who specializes in applied mechanics;

Dr. Thomas F. Malone, director of research, the Travelers Insurance Cos., Hartford, Conn. Dr. Malone is a meteorologist;

Dr. W. Albert Noyes, Jr., professor of chemistry, University of Rochester, Rochester, N.Y.

Dr. Roger Revelle, director of the Scripps Institution of Oceanography, University of California, at La Jolla, Calif.;

Dr. Richard J. Russell, professor of geography, acting dean of the Graduate School, Louisiana State University, Baton Rouge, La.;

Dr. H. Guyford Stever, professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.;

Prof. James A. Van Allen, Department of Physics and Astronomy, State University of Iowa, Iowa City, Iowa;

Dr. Fred L. Whipple, director of the Smithsonian Institution's Astrophysical Observatory, Cambridge, Mass.;

Dr. Maurice J. Zucrow, Atkins Professor of Engineering, Purdue University, Lafayette, Ind.

SECOND FORMAL SESSION OF THE PANEL ON SCIENCE AND TECHNOLOGY

THURSDAY, JUNE 2, 1960

COMMITTEE HEARING ROOM (214B),
New House Office Building, Washington, D.C.

The meeting convened at 10 a.m., Hon. Overton Brooks presiding.

OPENING REMARKS BY THE CHAIRMAN

Mr. BROOKS. The committee-panel meeting will come to order.

I want to say before we actually get underway that these pictures are not taken at committee expense. We are indebted to the major parties for the pictures and also personal friends of members of the committee. But there is no committee expense involved in the pictures.

I have just received a telegram from Dr. H. G. Stever:

Deeply regret that I will be unable to attend either session of June 2 or 3 meeting of your advisory committee. I hope you have a successful meeting.

We regret the doctor is not able to come. We thank him for the telegram.

I want to say that we welcome to the second meeting of the panel and the committee everybody who is here. Knowing that this is the busy time of the year for us all, I am sure I express the pleasure of everyone concerned that we have such a fine turnout, both of the committee and of the panel. There will be more coming in as we move along. Some of our members are rushing to clear their desks of urgent letters this morning, and some have calls and some have constituents, but they will join us as soon as they can.

We are sitting here today in this special meeting situation, not in any sense in a formal committee hearing. For this reason I have interspersed members of both the committee and the panel in these seats, not in accordance with any concept of seniority, but just as is convenient as people arrive. This is to help preserve the atmosphere of free exchange of ideas on both sides.

By now all members of the panel have received copies of the report on the first meeting of the panel and committee. If you need extra copies, let us know and we will furnish them. We have been very gratified with the flow of favorable letters which have come from many of the recipients of that report.

I trust that all members of the panel have also received their certificates of membership on the Panel on Science and Technology of this committee. I say this as chairman, that the members of the committee are very proud to be able to present such a distinguished group of scientists these certificates.

Plan for the meetings

As you know, we plan to have two mornings of sessions, starting at 10 o'clock each day, this morning and tomorrow morning. I have been pleased with the response to my suggestion that a number of papers be prepared by members of the panel, to be delivered some today, and the rest to be delivered tomorrow. I thought this would give us a point of departure for our discussions. At the same time, it is clear that we need not feel restricted to the subject matter of the papers in our following general discussion.

In response to a suggestion received from several members of the panel, we are also prepared to reserve a small block of time either this morning or tomorrow—I think it would be better tomorrow—for some discussion off the record, in case there are some matters members of the panel or of the committee to bring up that are better discussed off the record. I have purposely left the time open to keep this flexible to our needs.

It is also my thought that if there are some matters which either members of the panel or of the committee wish to pursue in greater detail, we could leave the afternoons open both days for these discussions on an informal basis. This can be done on the basis of smaller groups, with staff participation, too. My thought is that this would give the staff greater opportunity and greater freedom for general discussion with some of our distinguished guests who are here this morning. I leave this to the initiative and good judgment of all concerned. If some of you have other urgent business to attend in the afternoons, and I know some of the members of the panel do have that, then of course you are free to go and we will understand it fully.

Last time we met, and we heard from everybody, I called on Dean Russell of the Louisiana State University last, and he made a comment about that. So this time, in all fairness, I am going to call on Dr. Russell first.

Rollcall of the panel

Dr. Russell, I would suggest this: That before I formally call on you we have a rollcall here of our distinguished guests, that they may be formally entered as present on this occasion.

I have a list here of our guests. We have:

Dr. Edward J. Baldes, senior consultant in biophysics of Mayo Clinic, Rochester, Minn.

Dr. Clifford C. Furnas, chancellor of the University of Buffalo. Dr. Furnas is a chemical engineer.

Mr. Martin Goland, president of the Southwest Research Institute of San Antonio, Tex. Mr. Goland is an engineer, who specializes in applied mechanics. He delivered a very fine paper the last time he was here.

Dr. Thomas F. Malone, director of research, the Travelers Insurance Cos., Hartford, Conn. Dr. Malone is a meteorologist.

Dr. W. Albert Noyes, Jr., professor of chemistry, University of Rochester, Rochester, N.Y.

Dr. Roger Revelle, director of Scripps Institution of Oceanography, University of California, at La Jolla——

Mr. MILLER. Wait a minute, now. Wait a minute. [Laughter.]

Mr. FULTON. I was waiting for that.

Mr. BROOKS. All right. From the State of California. [Laughter.]

He, by the way, was absent last time.

So this is your first attendance. We are very happy to welcome you this morning, Dr. Revelle.

Dr. Richard J. Russell, professor of geography, acting dean of the Graduate School, Louisiana State University, Baton Rouge, La.

Dr. H. Guyford Stever, and we just have the telegram from Dr. Stever saying that he is not able to be present.

Dr. James A. Van Allen, department of physics and astronomy, Iowa State University, Iowa City, Iowa.

Dr. VAN ALLEN. Here.

Mr. BROOKS. Dr. Van Allen.

Mr. WOLF. We should correct the record, Mr. Chairman. It is the University of Iowa. There are two universities in Iowa. Iowa State is at Ames; the University of Iowa is at Iowa City.

Mr. BROOKS. Where is Iowa?

Mr. MOELLER. Where is Iowa? [Laughter.]

Mr. WOLF. That is all right. Go ahead, keep mentioning the name.

Mr. MILLER. If he continues to give that good southern pronunciation to Iowa, we will have to start talking about New Orleans. [Laughter.]

Mr. BROOKS. Dr. Fred L. Whipple, Director of the Smithsonian Institution's Astrophysical Observatory, Cambridge, Mass. And we are happy to have you here.

Dr. Maurice J. Zucrow, professor of engineering, Purdue University, Lafayette, La.

Dr. ZUCROW. Indiana. [Laughter.]

Mr. BROOKS. All right. Have your fun, gentlemen.

Mr. FULTON. Mr. Chairman, for the pro tem, I hope that when we read off the names and then read the names of the committee members so there will be no discrimination, each committee member be doctor pro tem for the day.

Mr. MILLER. I think everyone who sits on this committee during this tenure should be a doctor.

Mr. BROOKS. At least a doctor; perhaps above that.

Now, Dr. Russell, we are happy to have you, sir.

I suggest as the panel members proceed that they take the witness chair in the center and our technical director will be glad to stand by and assist you at any time that you may need assistance.

Dr. Sheldon, if you will, please.

Dr. SHELDON. Yes, sir.

Mr. BROOKS. Doctor, we are happy to have you back and happy to have everybody back. We gave you full latitude to decide what you wish to say at this meeting. Everything that you do say will be helpful, I am sure, to the members of the committee and their work in the Congress of the United States.

PAPER BY DR. RICHARD J. RUSSELL

Dr. RUSSELL. I wish to present various research needs and possibilities in the field of geology.

Areas of fundamental ignorance

We know very little about the crust of the Earth. We await better knowledge of the shape of the Earth to know where overseas places

actually are located. In North America we need repeated geodetic surveys. better knowledge of the distribution of gravitational forces, many refined tiltmeter observations, and other geophysical data to know how and at what rates the Earth's crust is being deformed.

Coastal California creeps northward at a rate of some inches per year in comparison with the Sierra Nevada; parts of the Northeastern United States rise appreciably in comparison with regions some distance away, and we know roughly many other areas of crustal movement at rates sufficient to justify a continuing inventory.

The composition of the outer part of the Earth's crust is imperfectly known. We need a chemical balance sheet and much more exact knowledge of both distribution and volumetric abundance of elements, minerals, and rocks.

We lag far behind the Russians here. For many years they have been drilling, in geometric pattern, holes to the basement rock in all parts of the Soviet Union.

Our own ideas are based on mine shaft and wells drilled in search of petroleum. Practically all of our information comes from exceptional places so that we have only distorted information, in comparison with that which would be obtained by spacing holes geometrically, without regard to known economic goals, so as to get informative, random sampling.

The water content of the Earth's crust is insufficiently known. We are woefully ignorant about permeability and porosity of rock at depth, and hence about rates of water movement. Even at shallow depth, where ground water is one of our most essential resources we are acutely ignorant about abundance, flow characteristics, and rates of flow.

In most places we seek ground water for its purity, but in a few for its impurity, for salts of commercial value.

We are now contaminating both surface and subsurface waters at rates that may threaten continuing habitation of some densely populated areas. But this readily available supply of water is only part of waters in the Earth's crust. Within recent years it is becoming apparent that crustal deformation is related to water at greater depth.

Volcanic phenomena, frequency of earthquakes, regional tilting and subsidence, and many other crustal phenomena will be more adequately understood only after our knowledge of water in the crust is improved.

With these investigations will come better understanding of movements of fluids and gases that will greatly enhance our knowledge of ores and ability to locate essential mineral resources.

Heat transfer values are poorly known. We have only crude data concerning the conductivity of rocks. It is amazing to find that the value of the vertical temperature gradient in the crust most commonly cited in texts and tables is one determined in Paris, shortly after Fahrenheit invented the thermometer.

In considering questions such as widespread use of the Earth's internal heat as a source of power, we have little basis today for estimating depletion rates.

This short list of areas of fundamental ignorance is by no means exhaustive. It points up our need for inventories, for gathering facts that are readily obtainable, provided that we supply necessary effort.

Interpretation of facts

After observation we come to matters of interpretation in the development and application of any science. Observations must pass from emphasis on qualitative to quantitative fact. Abilities to interpret are at hand but the interpreters badly need something like a handbook of geological constants that can be compiled only after our observations are much more adequate.

We are quite illiterate today about questions as simple as how an unconsolidated sediment becomes a hard rock. The basic mechanics of rock deformation await more adequate understanding of elastic and plastic properties of rock at depth.

It is commonly said that observation and interpretation mean little until one has a theory to test. Geologists have been fertile in providing theories, but have lacked adequate means for testing them. It is high time that we make more meaningful efforts.

For more than a century geologists have been mapping actively the distributional pattern of various rocks and structures. More recently, as a parallel activity, geophysicists have been observing many things, such as currents of electricity in the rocks, distribution of magnetic fields, residual magnetism in geologically ancient minerals, characteristics of travel of various types of waves in the crust, and the force of gravity at various places.

Both geologists and geophysicists formulate theories concerning the crust and its deformation. One group commonly disputes the conclusions of the other and both have advanced to the point where a showdown is necessary.

A few areas that have been mapped in extreme detail by geologists should be subjected to a variety of sophisticated geophysical tests to discover areas of agreement and find where conclusions may be faulty, on the basis of more refined observations and interpretations.

Have I wasted the time of the committee and panel in listing some areas of ignorance among Earth scientists? I think not. I will attempt now to outline briefly some practical results, with emphasis on what I believe are matters of public impact, should some of our deficiencies be remedied.

Practical results of geologic studies

1. *Public health.*—Relationships between geology and public health are rapidly looming in significance. Correlations between fluorine content of water and tooth decay, limestone and incidence of goiter, or the presence of supplies of deadly ground water in certain areas have long been known.

An association between minute amounts of selenium and sterility appears to be real. High incidence of cancer has been related to polluted water supplies, and possibly to natural radioactivity of rocks.

A penetrating study in the State of New York by a geologist, statistician, and epidemiologist distinctly relates incidence of maldeformations at birth to the geologic map.

With increasing pollution of ground water and increase in abundance of dangerous isotopes that did not exist before we began dealing with fissionable materials in a modern way, our needs for more detailed knowledge have become acute.

While the public is alert to the dangers of atmospheric fallout, and possibly overalarmed, it is now blissfully ignorant of what may be far more serious problems arising from pollution of both ground water and soil.

We may expect the rate of production of substances such as strontium 90 to double every 12 years, in keeping with our increasing need for energy. We must know how to dispose of these dangerous products in the safest possible way.

2. *Fuels.*—Geologists traditionally have been finders of mineral fuels. With coal, problems were relatively simple and our deposits are quite well known. Petroleum and natural gas passed more rapidly through an evolution from easy- to hard-to-find reserves; from production in domes and anticlines to requirements for locating shoestring sands and pinchouts.

The discovery of new reserves has been so successful that we have developed unwarranted complacency about future supplies. Though executives of several oil companies have expressed highly optimistic views, most experts agree that the peak U.S. production will come within a decade, and possibly within 5 years.

It will not only be necessary to improve methods of recovery, as was pointed out to the committee at our last meeting, but also to test every possible chance of locating reserves in places that are now considered as unfavorable.

Fissionable materials provide some electricity now and there is every reason to believe that they will do so in rapidly increasing amounts within the near future.

For most of the United States at present the block is economic. Costs appear to be on the order of twice those of processes employing conventional fuels. This is most fortunate for the reason that it is providing time for the discovery of methods of safely disposing of associated high-level waste.

But the tomorrow is not far away when technological breakthroughs occur that will lower costs and promote a mad rush toward utilization of fissionable materials as fuel and a terrific public demand for much cheaper electricity.

Geologists will not only be active in disposing of wastes but also may be seeking new mineral fuel sources as intensively as people with Geiger counters were searching for uranium a few years ago.

3. *New minerals.*—A new element in the mineral resources picture is the fact that many rare minerals of no known commercial value suddenly become highly necessary resources when new technological demands arise.

The Russians have several large institutions engaged in finding new uses for minerals. We lag pitifully, but we have done fairly well in finding new techniques for the discovery of metals.

It has been found that certain minerals act as scavengers for picking up minute amounts of metallic trace elements and that the quantities they contain are highly variable from place to place.

Here appears to be a key for placing mineral prospecting on a new, highly scientific basis. Most mining camps are located in places where rock is widely exposed at the surface, as in mountains, deserts, or arctic regions.

Trace element techniques in all probability will lead to discoveries in types of areas that heretofore have defied prospectors, as below thick overburdens of soil or soft rock.

The leadtime between discovery of techniques and realization of practical results in matters such as ore discovery could be shortened tremendously if the scientists concerned were more favorably supported.

The invention of the transistor and development of other electronic equipment, discoveries in metallurgy, and other technological advances create heavy demands for substances that were not long ago regarded as worthless. We have little idea about the most urgent mineral needs of the future, but they are certain to change rapidly, and there is no question about the necessity for training people capable of solving each new demand as it arises.

What point is there in bringing questions of this type before your committee? I presume it needs background information. And I also presume that the Congress will from time to time become involved in matters such as I am attempting to bring into focus.

Government organizations concerned with geologic research

Various governmental agencies are engaged in fostering the development of solid Earth sciences, and probably most of them could accelerate their programs effectively if given the opportunity.

The Coast and Geodetic Survey, Geological Survey, Bureau of Standards, and various other agencies are well established and are capable of increasing their efforts.

The National Science Foundation, Office of Naval Research, some other Defense agencies, and various other governmental organizations have keen interests in specific parts of any program designed to increase our knowledge about the Earth and capabilities for using its resources.

Many of our most fundamental discoveries are being made by organizations such as the Carnegie Institution of Washington and Rockefeller Institute, for the reason that they have keen appreciation of the value of basic research.

Proposed institutes for geologic research

It has been proposed that institutes be established for services such as providing chemical analyses of rocks and minerals, age determinations of rocks, discovering new uses for minerals and rocks, and for collecting data on magnetism, radioactivity, gravitational forces, and rock deformation.

A special standards institute is needed for providing reference samples of rocks and minerals with known analytical, radioactive, and spectroscopic properties. It should be equipped with instruments so highly specialized and costly that they are out of reach of universities and comparable research institutions.

The National Science Foundation and Office of Naval Research could serve as sponsors of these institutes, as might the Geological Survey or probably several other governmental agencies.

It is essential in meeting public needs that more satisfactory methods be devised for continuing financing of important research activities, with less emphasis on fiscal years, so that projects may be carried out more effectively and more economically.

Better methods are needed for cooperation with universities, the traditional source of new ideas and mainstay for supplying to Government, industry, and themselves capable and highly trained personnel. The idea should never be minimized, however, that if research institutes, governmental and private research agencies, and industry provide opportunities so attractive that universities are no longer able to retain their most talented people and provide adequate support for basic research, the entire program of national development and survival will short-circuit and fail.

Several of the proposed research institutes should be located in universities but be supported nationally for the reason that their services are primarily national in scope.

While it is highly desirable from many angles to raise the educational level of the masses, it must be realized that the most pressing questions of development and survival are not related to broad, general programs of education.

For its own protection, what the public needs most are scientific and technological advances that will result from the efforts of a comparatively small number of extremely talented individuals. These must have highly specialized training such as will be available only in a small number of institutions and universities, each of which must be provided with intellectual and material resources that it would be unwise, indeed impossible, to duplicate at many places.

Thank you.

Mr. BROOKS. Thank you, Dr. Russell, for a very excellent statement.

Now, Doctor, before you get away, my thought is this, and we are just feeling our way along here, that after each statement that we have 5 or 10 minutes of questions, if the members of the panel or the members of the committee desire to ask any questions, if that is agreeable with Dr. Russell.

Dr. RUSSELL. Certainly.

Mr. BROOKS. Are there any questions?

Mr. Miller?

COMMENTS BY REPRESENTATIVE MILLER

Mr. MILLER. I would just like to compliment Dr. Russell in pointing up the necessity for doing more work in the Earth sciences.

I feel that we have gone off into space. This has been prompted a great deal by our own self-interest and our self-protection. But in the long run it is the knowledge that we are going to have to obtain and develop from the Earth sciences, from oceanography and other fields that mean the continuance of life on this Earth as we know it today.

I think he has pointed that up very well, and I think he is to be congratulated for it.

Dr. RUSSELL. Along that line, I would like to mention that I spent a good deal of last week up at Fort Monmouth, and I liked what I saw. The Signal Corps of the Army is doing amazing things up there, they are excellent.

But a thing not to be overlooked is that the sea, the air, are all channels of communication between points that are Earth based. Anything starts from a point on the Earth and most things wind up at a

point on the Earth. And until we know more about the surface of the Earth, we are a little ignorant, perhaps a little too complacent about sending things through these channels of communication.

Mr. BROOKS. I think that is an excellent statement, Mr. Miller, in reference to your subject this morning.

Mr. Fulton?

COMMENTS BY REPRESENTATIVE FULTON

Mr. FULTON. The problem comes up of what a system of measurements should be. We have many systems of measurement in the world today, and that brings up the question of the purpose of this committee.

Don't you think that this committee should be part of a seed corn or part of the directional basis of trying to bring the U.S. system of measurements to conform to a world-unified system of measurements?

Use of the metric system

For example, I have entered a resolution for the orderly adoption of the metric system in all fields in the United States. The chairman likewise has one of those resolutions in.

What do you think of that?

Dr. RUSSELL. If I may use a few minutes, I have thought a lot about this.

Mr. MILLER. Doctor, before you begin, may I say, as chairman of the subcommittee that has been designated to hear these bills, I just sent out to get one of them, we are going to try to start hearings on them next week.

I was going to ask members of the panel either to comment on it or if they will, to write to the chairman or to me, giving us statements that we could file in the record.

Mr. FULTON. Just before a statement is made, may I put my other question and then you can comment on them all?

You have brought up the question of measurement as far as three dimensional space is concerned in connection with our planet.

A point of reference in space and time

I have another resolution in; I will throw this idea out for what it is worth: to me there is no place where you begin measurements on the Earth.

Secondly, there is a difficulty in deciding where you would do it, and, of course, putting it in a system of time.

I realize that they tried to do it in the year 1900, but that is 19 times 10 to the second power.

My suggestion is this, and I have a resolution on it: Why don't we try at this point to work out a system of connecting Earth measurements on this planet with astronomical measurements, both in time and in place?

And my suggestion is adopting the first point of Ares, at the close of the year 1999 when you would then have the beginning of the third millennium and that would be 2 times 10 to the third power, as an easy mathematical way of stating it.

Then, picking a place that we say is the start of the measurements and then refer it by a radius to the center of the Earth by calculating

it, and then you have a line from the center of the Earth to a point somewhere—it may be on the Earth's surface, but it is at least someplace that is not in process of movement on the basic basalt.

Then, from there, when you put your missile off for the Moon, you can pretty well calculate exactly where you are starting from and where you are going to end, and we have no such system now.

As you know, some of us have been on these Cape Canaveral shots, we have been missing by a degree, degree and a half, 2 or 3 degrees.

Why don't we then have a system in time and place that takes a point of reference, subtended to the center of the Earth, and then project that into astronomical distances and times, instead of just using M–31 for astronomical distances? Why don't we start trying to be more exact?

I know, I think it will be Dr. Whipple who will immediately destroy this idea for me, but the idea is this: If we are going to take a starting point for time and distance, let's do it scientifically and let's start to try to come up with it so we know what we are doing with it basically.

Mr. BROOKS. Did you wish to reply to that, Doctor?

Dr. RUSSELL. I would like to comment on the first remarks, first, concerning the system of measurements.

Mr. FULTON. I think if you will reply to Mr. Miller on this one——

Mr. BROOKS. I used the wrong word, "reply." Do you wish to comment in reference to the matter?

ADVANTAGES OF STANDARDIZED MEASURES

Dr. RUSSELL. Yes.

I might say that I have lived in Europe for more than 3½ years. I have been a member of the faculty of two European universities, and I have a feeling that the question implies a great deal more than simply adopting a metric system. The question is most fundamental in our whole scheme of education in the United States.

We have a subject which many children find difficult, it is called arithmetic. Now arithmetic consists of adding, subtracting, multiplying, and dividing.

Our children, for years, in studying a thing called arithmetic are actually studying the English system of weights and measures: how many square yards of wallpaper it takes to cover a certain area so many feet and inches long.

The European child learns how to set a decimal point over to the proper position, comes up with the answers. He gets into alegbra. At the age of 16, as a study from Belgium shows, the average European child is 2 years ahead of our American child.

Two fundamental reasons: One, we have another very difficult subject called spelling, which few of us ever make much headway in. But to children it is very difficult because of an irrational pronunciation of a language.

To go to a phonetic language is altogether too much, but, two, is this matter of arithmetic, this is the second most difficult subject for most children, and this is simply because we have such a complicated and obsolete system of weights and measures.

The scientists by various degrees of course have gotten away from this. I think in metric units, I wish that all geologists worked in metric units. Chemistry, physics, various fields do their work in metric units.

Now, of course, the impact commercially, changing the threads of screws, and the various things that are implied industrially are perhaps overwhelming.

I have been informed that the metric system, possibly in the Congress back in the 1880's—that the metric system became legalized in the United States. This statement was made at a meeting of the American Association for the Advancement of Science in Indianapolis a year or two ago.

But in spite of its legality, its universal adoption in my mind, it would mean far more than all the economies it would bring, it would revolutionize our educational system. Our public schools are not so bad. I have four grandchildren between the ages of 11 and 18 who certainly know far more at their ages than I did. They get some of it from TV, other places, but a great deal of it comes from the school.

Our whole system has this millstone around its neck, of the obsolete system of weights and measures.

Mr. MILLER. When we say, which is the lesser, fifteen-sixteenths or twenty-nine thirty-seconds, you can't pick it right out of the air.

Dr. RUSSELL. The engineers are particularly bad offenders, because the architects, for example, think in terms of quarters, sixteenths, thirty-seconds, sixty-fourths. I don't know how many millions of dollars that costs the United States per year, the fact that the architect's scale is such an irrational scale.

For certain fundamental engineering courses, the units from one branch of engineering are so different from those in the next that I have made the statement many times, it is the wise student who knows he is taking the same course over again.

Mr. FULTON. Very good. [Laughter.]

Mr. BROOKS. Doctor, did you wish to——

Dr. NOYES. I want to say one word in support of what Dr. Russell has said. Because those like myself who have to teach courses in which there are both scientists and engineering students have an awful time.

The engineers have pounds, yards, and half the class is dealing with those units, and the other half, chemistry majors, are dealing with the metric system.

I think somehow the timesaving which would be involved would be very important if we could go over to a metric system.

Mr. BROOKS. I can see two excellent witnesses here for Mr. Miller's subcommittee. [Laughter.]

Mr. MILLER. I see about 10.

Dr. ZUCROW. I would like to make a statement. For example, we have a very important engineering science known as heat transfer, and this is getting to be much more important as time goes on because heat transfer is a phenomenon that is important in space vehicle design and improving all types of engines.

One finds that a large fraction of the time expended in working heat transfer engineering problems is consumed in changing the units employed.

Now I think the additional time we spend in teaching all our sciences in English units and the additional time spent in working problems with those units could be more profitably spent in other ways.

Now whether it is going to be possible to change and get everybody to adopt the metric system, because all our machine tools and standards are in the English system, is another question.

But from the point of view of logic and sense, I endorse what Dr. Russell says.

Mr. FULTON. Could we prepare a form of plan by industry that you had a gradual changeover, maybe under Presidential direction?

Mr. MILLER. That, I think, is one of the things, Mr. Fulton, that we will turn over to the Bureau of Standards and their study, to try and come up with answers to some of these questions and make some suggestions.

Mr. BROOKS. Dr. Whipple, we are going to call on you next.

After Dr. Whipple makes an observation or asks a question, I think we have consumed 15 minutes in questioning Dr. Russell, and we had better proceed with the other statements. Then we can come back in the time that we still have.

Mr. MILLER. Before Dr. Russell——

Mr. BROOKS. I recognize Dr. Whipple.

Dr. WHIPPLE. I merely wanted to suggest this unit of acceleration—furlongs per square fortnight.

Dr. NOYES. British thermal units per gram; that is pretty bad.

Mr. FULTON. Have Dr. Whipple, on commenting——

Mr. BROOKS. Let's do this, though, if we are finished with Dr. Russell, Doctor, we thank you very much.

Now it so happens that Dr. Fred Whipple, Director of the Smithsonian Astrophysical Observatory, is the next on our list. And, Doctor, if you would step around here to the witness table, sir, we would be happy to have your statement.

I want to say this: We have four prepared statements. Isn't that right?

Dr. SHELDON. Three today.

Mr. BROOKS. Three prepared statements.

We will proceed with them, and then we will have ample time, I am sure, to ask questions generally.

Doctor, have a seat, sir.

Dr. WHIPPLE. Thank you.

Mr. BROOKS. We would be happy for you to proceed with your prepared statement, Doctor.

Don't leave us, Mr. Miller.

Mr. MILLER. I am not going to leave.

Mr. WOLF. I would like to have the record show that Dr. Whipple was born in Red Oak, Iowa, in 1906.

Mr. FULTON. Does that qualify him?

Mr. WOLF. He had a gift to give to the world. Why not? [Laughter.]

PAPER BY DR. FRED L. WHIPPLE

Dr. WHIPPLE. Chairman Brooks and members of the Committee on Science and Astronautics, at our first meeting I presented, bashfully, a germ of a thought concerning certain types of essential research pro-

grams that tend to be neglected in our present national system of scientific support. At that time my ideas were not clearly enough formulated for a proper presentation. Now I can expand the picture a bit in the directions where my own experience and observation may be of significance.

The type of research or research engineering that I have in mind will generally be a cross-discipline type of activity. It will rarely fall entirely within any of the known major disciplines and rarely will an individual scientist or engineer have sufficient breadth to plan or conduct the entire research alone. Frequently, too, the nature of the research will also fall between the purviews of recognized sources of appreciable research funds.

Study of the lunar surface

To particularize the discussion, I shall now choose an example, which may or may not be entirely representative of the various factors I have just mentioned. Nevertheless, the problem of the nature of the lunar surface, both from the point of view of lunar science and the engineering point of view for lunar landing, is a significant problem and illustrative of the point.

No one on the planet *knows* (of course I *think* I know the answer) whether the Moon's surface is covered with a considerable thickness of dust or is a fairly rigid, hard surface suitable for supporting substantial landings. Nor will a few hard or soft landings with limited equipment necessarily give us a general answer to this question.

Obviously the question is of the greatest importance theoretically and practically in lunar exploration. I believe that this problem can be answered in the laboratory at about 1 percent the cost of a rather simple lunar probe and with adequate certainty for the engineering requirements.

We know, at least within limits, the physical environment that affects the Moon's surface. We can vary the experimental conditions and try various situations that may have occurred on the Moon's surface over an interval of time, and we can speed up the time factor. To my knowledge, there is no adequate experiment of this sort underway, although it is possible that I am not informed as to the recent progress.

I think our space program here has demonstrated a rapidly growing tendency of modern times; namely, that real progress can be made only when the "purest" of scientists and the "most practical" of engineers work shoulder to shoulder along with men of all intervening degrees of theoretical and practical experience. This illustration, which I am expanding a bit just to be indicative of the problem, illustrates this need. It is not truly an experiment in astrophysics, in geology, in chemistry, or in physics, but it embraces all of these subjects as well as demanding laboratory skill in high vacuum techniques, in "corrosive" ion propulsion, in electrostatic control, and in various techniques for handling pulverized material.

The laboratory answers can be partially checked by comparison with observed radiative properties of the Moon, in the visual infrared and radio regions of the spectra. There are a considerable number of laboratories over the country where all of these skills and sciences could be brought to bear upon the problem. Also, I believe that

there are a sufficient number of research men who would be interested in conducting the experiment if they were encouraged by the promise of proper support.

Problems of financial support

But who gives the support? The project is too large for a university and for all but the greatest foundations to support. It hardly rates as an experiment essential to defense, although it certainly bears upon it. It is not exactly a problem in basic research for the support of the National Science Foundation. Possibly if an investigator pushed hard enough, he might find a committee somewhere that would approve a limited grant for a "study" of the problem.

Perhaps it falls closest to the purview of the National Aeronautics and Space Administration and perhaps, indeed, NASA is doing something about it. But NASA is suffering from financial malnutrition because of the expected/unexpected increase in cost of conducting the experiments to which it is committed. In the long run, my guess is that the Moon-surface experiment will be carried out inadequately, that rather large expenditures will be made to answer the question mostly from the Moon itself, sending probes, and in the end we will, by good luck, come out with an answer that is close enough to the truth, engineeringwise, that no disaster will occur.

Seismic research

I mention another example not in the field of my own specialty. This is related to the first example and concerns studies of the planets, including the Moon, by seismic methods, moonquakes. Here is an old field of research on the Earth and of the Earth, which has received only a modicum of support, except in a few specialized problems such as oil prospecting. Seismology received a mild "shot in the arm" because of the International Geophysical Year.

Yet we plan at enormous expense to place simple recording seismographs on the Moon and planets. Our purpose is to learn about these bodies and certainly something will be learned from exceedingly simple experiments. When we consider the cost of the space science experiments compared to the backup research needed in seismology on the Earth, we find that the ratio is like the ratio of market value to earnings for a modern electronic stock, a hundred to one or so. The basic research in seismology has been conducted by a handful of faithful devotees for a number of decades, and the support is so small as to keep progress at a highly efficient rate, considering the number of workers, but the results are actually coming out at a low level because the total amount is not great.

Our lack of knowledge in this field has proved highly embarrassing internationally, very recently, with regard to the problem of detecting atom bomb tests. We still can't predict earthquakes; for example, Chile.

I put the question that was presented to me by one of our most able seismologists: "Do we know enough about seismology and the interior of the planet Earth to plan a proper experiment for the Moon, Mars, or Venus?" I do not know the answer to this question, but I am certain that a much more positive answer would be forthcoming should we find a way actively to support the backup seismological research that is obviously needed. Dr. Russell has just presented a

much broader point of view on geological needs—certainly my example represents only one of the many needs in this basic research field.

Meteorologic research

At our last meeting Sverre Petterssen discussed the brilliant possible future of meteorology on this planet and on others and pointed out the fact that—

since the end of the last World War meteorology has been a neglected scientific field.

Clearly the remarkably successful Tiros experiment has demonstrated that future meteorological satellites can provide a "completely new horizon" in meteorology and atmospheric sciences and in the practical matter of weather forecasting.

A number of leading meteorologists have been pressing for the organization of a National Institute of Atmospheric Sciences. The creation of such an institute would be a milestone in the progress of meteorology and, among its other important contributions, would provide the essential backup to our space science program, both for the meteorological satellites about the Earth and for our meteorological experiments above and in the atmospheres of other planets.

Meteorology, I believe, embraces all of the physical sciences and perhaps some of the biological. Until the active research workers in the major subsections of meteorology are brought together "under one roof" and given an opportunity to interact scientifically, I do not believe that we will attain the degree of progress that is abundantly promised and urgently needed in the near future.

Only with such an organization can our enormous expenditure in meteorological satellites and planetary atmospheric research be able to reach its full potential. At the moment, I do not know whether or how the National Institute for Atmospheric Sciences is to be financed, but my impression over the last year or two is that its future is somewhat uncertain.

High-altitude balloons

In another related area, in the highest part of the atmosphere and in space sciences, one of the least expensive and most valuable backups to the space program is the high-altitude balloon. I will not elaborate on the problems here except to say that the scientific balloon program is essentially a homeless orphan except for the very limited but highly effective support given particularly by the Office of Naval Research and to some extent by the Air Force.

This matter of responsibility for the potentially precious balloon program should be settled at the earliest possible moment and supported adequately. Dollar for dollar it should pay off at somewhere between 10 and 100 to 1 over satellites and space probes in terms of space science results.

Furthermore, the balloon program involves generally a much smaller and less rigid scientific effort than the space program, with much simpler problems of coordination, guidance, tracking, and so forth. Hence, it is much better suited for the university researcher than is the satellite program. This is very important to me as it still seems to be true that most of the major scientific progress comes

from within the universities and research organizations closely associated with universities.

Incidentally, the tendency of our present space program away from from the university impresses me as a step in the wrong direction.

Meteoritic research

I would enjoy expanding on problems in the field of my own specialty, viz, meteoritics, but I will spare you the details of this effort except to attach as a possible appendix to this discussion a paper I wrote for the National Academy of Sciences on this subject about a year ago, "Solid Particles in the Solar System."

If you wish, I would be glad to introduce this as an appendix to the formal report.

Mr. FULTON. I so move, Mr. Chairman.

Mr. BROOKS. We will accept it as an appendix to your statement.

Dr. WHIPPLE. Thank you.

I will summarize the paper by saying that the groundbased activity to back up our space engineers in the field of meteoritics is still operating at a snail's pace compared to its proper rate. By saving a few hundred thousand dollars a year in meteoritic research, we may lose hundreds of millions of dollars in our space program.

Radio astronomy

There are other aspects to our general problem. One concerns a backup program in which we do indeed have very fine support financially and organizationwise, radio astronomy. This field is extremely well covered except for one small area, radio meteor research. Nevertheless, there are extremely serious problems in keeping the radio lanes open for radio astronomy. Even the satellites sometimes impinge upon these bands in the radio spectrum, and it is possible that the House Committee on Science and Astronautics can assist in protecting this very excellent effort which is now underway in radio astronomy.

"Telepuppets"

I will mention another area in which I am certain that groundbased developmental engineering, not exactly basic science here but developmental engineering, could be extremely important to the space program; that is in the case of the remote-controlled robot. The idea is that a robot in space can do everything that a man can, at far less expense, weight, and emotional concern, so long as there can be television contact between the robot and a man who is controlling it on the ground.

Now one of the major problems of all space research, space operations, military as well as scientific, is that of reliability of equipment in space. Once you multiply the remote-controlled robots and have them sufficiently subtle in their operation so that they can repair each other as well as the equipment aboard, then the problem of reliability will have been essentially solved. The system will operate to any distances where communication by television and remote control are practicable.

Now to my knowledge not very much is being done officially for the programs. I insist that it does not negate but rather supplements

in the most essential fashion the work of Project Mercury, man in space.

I won't make an attempt to list other neglected fields of research, simply for lack of time and lack of knowledge in many cases. Generally speaking, as an astronomer, I am embarrassed by the large number of reasonable questions about the Moon, the planets, interplanetary space that astronomy cannot answer.

Costs and manpower

In defense of the astronomer I point out that the total cost of launching and tracking one Earth satellite is adequate to build the observatory with the greatest telescope on Earth, the 200-inch Palomar reflector.

In answer to criticism that even with proper funds there are not enough astronomers to expand the astronomical frontier, I can only say that astronomers have always welcomed other scientists as colleagues and have depended upon the engineers to help us with our most important equipment. Also, we are training young men rapidly and have facilities to train many more than are available. Various programs of the National Science Foundation are of great assistance in this matter.

I am trying to point out why astronomers can't answer a lot of questions that we should. Until very recently, astronomical financing has been at an unbelievably low level. I grant that astronomers have not been aggressive enough in their demands for adequate support. It is a fact, that within the decade, I sat in a formal discussion where three of the leading astronomers in the country argued that a million dollars a year was an excessive amount of Government support for proper astronomical progress needed. I may say that astronomers are a bit more ambitious today. Nevertheless, I consider the funding of astronomical research to back up the space science program as broadly inadequate except in the field of radio astronomy (and there barring radio meteor astronomy).

Need for fundamental research

To generalize, it is my thesis that much of our national space program is inadequately backed up by fundamental research and development essential to its proper growth and execution.

Probably this neglect of background research results from the fact that no organization within this land having sufficient funds for this backup research has the authority and the assigned mission of supporting it.

Now I do not wish to imply that a space experiment or project executed on a crash basis with inadequate foundation studies, is necessarily bad. We all realize the enormous importance of early experience and research to our national welfare, so that an expensive, calculated risk can oftentimes be justified as a better investment than a less expensive but delayed result. Oftentimes, too, the intuitive judgment of an inspired scientist or engineer may surpass a conservative development by a mediocre "research group." I am not criticizing those who have worked so tirelessly to develop quickly much needed experimental equipment, rocket propulsion systems or other techniques essential to our early mastery of space.

My plea is for the proper support of the space programs that are now envisaged, for which we have time by acting quickly to improve the end result markedly without great cost, measured either in dollars or in delay of fulfillment.

Maintaining a balance in effort

The problem is not to be solved simply by adding more funds in total, but rather by guaranteeing that a modest fraction of the research and development funds be made available for the basic work that needs to be done.

The problem is similar to that of protecting research funds when they are combined with research and development funds. As is well known, and happens yearly throughout our R. & D. budgets, a squeeze or reduction in the budget never strikes the small 10 percent item of research at the same fractional level that it strikes the large item of development, the 90 percent. In practice, the cuts are taken more or less equally from both, until the research funds are largely eliminated. In many cases, a frantic scrambling recovers some of the research money so that its research support does not die completely.

This background support for the space program bears a similar relationship to the heavy engineering expenses of propulsion units, launching fields, tracking systems, and other large expenses which inevitably, are underestimated because they, themselves, are new developments in unproven territory.

As a concrete concept to spur our thinking, it seems to me possible there should be set up an individual or a group with a separate protected budget, possibly in the NASA or National Science Foundation, with the mission (*a*) to study the problem of backup research for the space program, (*b*) to encourage by various means research in critical backward areas, and (*c*) to fund research programs as required when they do not fall easily in the normal disciplines or categories of funds.

Clearly a heavy responsibility in scientific and technical vision would lie on the shoulders of such an individual or group. Staffing would be a most critical problem.

Perhaps some other type of solution would lead to a better result. I mention this one simply to try to "start the ball rolling" in our thinking, to make a "strawman." I am sure that you gentlemen, with your much broader understanding of governmental and financial aspects, can find a solution to this very real and urgent problem.

Thank you for this opportunity.

(The appendix to Dr. Whipple's statement, entitled "Solid Particles in the Solar System," is as follows:)

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SOLID PARTICLES IN THE SOLAR SYSTEM

(By Fred L. Whipple, Smithsonian Astrophysical and Harvard College Observatories, Cambridge, Mass.)

INTRODUCTION

Solid particles in the solar system are here defined as particles greater than molecules and smaller than planets; they move about the sun in free orbits and are not physically attached to planets. Comets, asteroids, and natural satellites might well be included in the subject matter but will be mentioned only as they are related to smaller particles in the solar system.

Detailed knowledge of the physical structure, composition and orbital distribution of particles in the solar system is of particular current interest because the particles constitute a potential hazard to satellites, space probes, and space vehicles. Both the designers of space equipment and the operational planners require precise knowledge to protect equipment and operations against the effects of meteoritic impact.

Meteoritic material in the solar system can yield fundamental information on the origin and nature of comets and asteroids, which in turn can provide a basis for the development and verification of theories about the evolution of the earth, the planets, and indeed the solar system as a whole.

Interactions of meteoritic material with interplanetary gases, ions, and electrons can yield statistical information relating to the nature and occurrence of gaseous material in the solar system, particularly corpuscular radiation from the sun. Such data may be critical in determining average conditions of the interplanetary gases. Furthermore, interactions of meteoritic material with the moon will aid our understanding of the lunar surface and lunar history. Conversely, exploration of the lunar surface may tell us much about meteoritic material in space.

To include a thorough summary of our knowledge about solid particles in space would unduly lengthen this discussion. Some background material and a few recent results are presented in the next section. Attention centers chiefly on important researches that should be conducted both in space and from the surface of the earth (discussed in subsequent sections). A review of this research brings into focus a striking fact: an enormous amount of ground-based meteoritic research is urgently required. Such research will strongly influence the design both of space vehicles and of space experiments and will, at the same time, answer some specific questions about the nature and motions of particles in space.

Ground-based meteoritic studies can provide some 80 percent of the necessary information about the nature and distribution of particles within 1 astronomical unit of the sun. Extensive studies from space vehicles are in fact needed only to discover unexpected meteor streams or characteristics of meteoritic material in space. Extrapolations beyond the earth's orbit concerning the numbers and orbits of meteoritie particles will very likely become increasingly unreliable with solar distance and probably cannot be entirely satisfactory for space-vehicle design at the distance of Mars. From the ground we seem to have done only about 10 per cent of the pure astronomical research on meteors that could and should be done and less than 1 per cent of the laboratory and range experimental work urgently needed. Experiments with ultravelocity particles, augmented by theoretical developments, will provide fundamental ballistic data from which we can interpret space and ground-based observations and can construct theories of the true nature and motions of solid particles in the solar system. The general subject of meteoritics is in a sorry plight because of lack of interest generally by the scientific community.

CURRENT METEORITICAL RESULTS

For general reviews of our present knowledge about solid particles in space and methods of studying them the reader may consult the following: Whipple and Hawkins [1959], Öpik [1956, 1958], Whipple [1958], Levin [1956], Kaiser [1955], and Lovell [1954].

To date the results of meteoritic impact experiments on rockets and satellites have been reported by two groups in the United States and one group in the Soviet Union. In all cases successful experiments have involved ultrasonic impact measurements utilizing piezoelectric detection equipment on surfaces exposed to space, a method first developed by Bohn and Nadig [1950]. The results obtained by Dubin [1958] at Air Force Cambridge Research Center, by the group at the Naval Research Laboratory including LaGow, Schaefer, and Schaffert [1958], and by the Russian experimenter Nazarova [1958] agree fairly well regarding the impact frequency on a flat surface exposed randomly in direction from a near-earth satellite. Impacts are recorded usually in the range 0.01 to 0.09 m^{-2} sec^{-1}. Unfortunately the calibration of the equipment used remains so doubtful that interpretation in terms of particle momentum, energy, velocity, or mass distributions is uncertain by a factor of some 10^4 times. The results, therefore, are as yet no more reliable than those obtained by the indirect methods, particularly extrapolation from much larger particles as determined by

photographic techniques or from van de Hulst's [1947] estimates based upon observations of the zodiacal cloud (probably the most reliable method for total mass influx). It appears likely that the total influx of solids on the earth amounts to a few thousand tons per day, mostly in the form of small particles.

Space vehicles will rarely encounter meteoritic bodies larger than dust. The probabilities of such impacts are fairly well known; some difficulty remains in calibrating the mass corresponding to a meteor of known velocity and luminosity or ion production in the atmosphere. The meteoritic hazards are not particularly great although they must be considered seriously in planetary missions and deep-space probes.

The most precise observational studies of meteors have been made by the two-camera photographic method in the Harvard Meteor Program. The Baker Super-Schmidt Meteor cameras have photographed some 6,000 meteors simultaneously from two stations, and many results have been obtained by Whipple and Jacchia [1957], McCrosky [1955a, b], Cook and Hughes [1957] Whipple and Wright [1954], Whipple and Hawkins [1959], and Whipple [1954]. Extensive photographic spectral studies of meteors have been conducted by Millman [1955]. The radio observations of meteors can yield radiants and velocities for meteors considerably fainter than those detected by the photographic method, i.e., to the 8th effective visual magnitude or fainter, as compared with the 4th or 5th by photographic detection. Major studies have been conducted by McKinley [1951] in Canada. The determination of radiants is due largely to the Manchester, England, group under the direction of Lovell [1954]. Particularly active at Manchester have been Clegg [1948], Hawkins [1956], and Gill and Davies [1956]. All the radio meteor work in the United States has been concentrated on problems of radio wave propagation, upper atmospheric research, and communication. Ellyett, after his initial studies in England, has with Keay [1956], continued radio meteor studies in New Zealand, and Weiss [1955], from southern Australia, has also made studies. Considerable activity in radio meteor research is developing in the Soviet Union, but the published results are sparse.

The radio and photographic studies together show that to approximately the 8th equivalent visual magnitude all meteorites move in closed orbits and belong to the solar system. The number of hyperbolic meteors, coming from interstellar space, is at most 1 per cent of the total. The orbits are mostly direct and of low inclination (about 80 per cent) with no apparent relationship to the asteroids. The photographic evidence clearly indicates that approximately 90 per cent of all visually observable meteors are of cometary origin [Whipple, 1954]. No information is yet available on the orbits of dust grains except that the dust is chiefly responsible for the zodiacal cloud and is largely confined to the general region of the ecliptic. It is safe to assume that near the earth's surface all meteoritic material travels in the velocity range from 11.3 to 73 km/sec, except conceivably for a small number of particles knocked off the moon by meteoritic impact or captured temporarily in orbits about the earth. No proof is yet available that these two latter classes of objects exist.

The photographic meteor studies by Jacchia [1955] and McCrosky [1955a, b] indicate conclusively that ordinary meteors are extremely fragile bodies. McCrosky shows clearly that many are crushed by dynamical pressures of 0.02 atmosphere. Unpublished evidence obtained by Cook and Whipple suggests strongly that the densities may be extremely low, possibly below 0.1 g/cm^3, and that the masses are probably greater than previously expected ($\sim$10 g for 0th magnitude). The spectral researches by Millman [1955] indicate that meteoritic material is similar in general chemical composition to the heavier elements in the solar system, but no accurate determinations have yet been made of chemical abundances in meteors.

Nothing is known about the density or chemical composition of dust in the solar system, although it is presumably cometary in origin. The densities are very probably higher than those believed to occur for the brighter meteors. Fine meteoritic dust captured in the atmosphere still remains to be identified positively, although many studies of "meteoritic dust" have been made. Meteorites found on the surface of the earth have been analyzed extensively by chemical, physical, metallurgical, mineralogical, and nuclear techniques. The consensus is that they arose from two or more asteroidal masses which were shattered into many pieces by many successive collisions. That a number of meteorities have existed in the solid state for some 4.5×10^9 years is evidenced by the ratio of A^{40} to K^{40} [Stoenner and Zähringer, 1958].

Spallation products from cosmic rays in meteorites place an upper limit to the total etching rate of solid surfaces exposed to space. Whipple and Fireman [1959] have shown on the basis of Fireman's measurements of the argon isotopes, A^{38} (stable) and A^{39} (260-year half-life) in meteorites, that the etching rate does not exceed 2×10^{-7} cm/yr for the few meteorites studied to date. If this etching is produced primarily by corpuscular radiation from the sun the rate at the earth's distance should not exceed 3×10^{-7} cm/yr and may possibly be somewhat smaller. The accuracy of this value can still be improved by better determinations of the spallation and shielding effects for cosmic rays of high energies. The etching effect is trivial, in practice, even for optical surfaces exposed several years in space.

A measure of the maximum etching rate on solids in space provides an upper limit to the average amount of corpuscular radiation sent out by the sun. We may assume that the corpuscles are largely protons moving radially from the sun with energies of hundreds or thousands of electron volts. Sputtering occurs on solid surfaces. G. K. Wehner has kindly provided the following tentative estimates of the sputtering rates of protons on iron: 0.5 atom/proton for 10,000 ev or more, 0.2 at 500 ev, and ~0.02 at 100 ev, all at normal incidence. He finds that the rate is greater for moderate angles of incidence, and so I adopt twice these values as applicable to the projected hemisphere of a spherical particle. Also, to apply the results at the earth's distance from the sun, I adopt an etching rate of 3×10^{-7} cm/yr. The result is an upper limit to average solar corpuscular radiation as shown in Table 1.

TABLE 1.—*Upper limit to corpuscular radiation at Earth's solar distance*

Proton energy, ev	Proton velocity, km/sec	Number, cm^2
500	310	200
1,000	440	140
5,000	980	40

NEEDED EXPERIMENTS FROM SPACE

In the following pages I list some possible types of experiments to be made from space vehicles. Certain critical experiments will be discussed briefly, with comments which are strictly my own opinion and may be subject to considerable alteration as space technology progresses.

Impact phenomena by natural particles impinging on exposed surfaces

The various types of experiments that may be used to study impact phenomena include the following:

Sonic—The utilization, for example, of piezo-electric crystals as detecting mechanisms, the only method successfully used to date in space.

Radiative—the emission of radiation by impacts, measured presumably by photoelectric cells or other highly sensitive radiation-sensing devices with short time constants.

Cratering—the cutting of wires, the puncturing of sheets or thin films, etc., to produce reactions measurable by changes in electrical conductivity or other physical properties.

Large-scale puncturing—the puncturing of thin sheets, in conjunction with mass measures, to determine area and thus density (suggested by McCrosky).

Large-scale cratering—direct study of surfaces, either by recovery from space or by television techniques in space.

The techniques listed do not generally measure the direction of motion of the particles in space unless additional equipment is provided. Furthermore, the experiments do not necessarily separate mass and velocity as independent parameters. Hence, these techniques, if they are to yield adequate information about the solid particles in space, must include the following variable factors: (*a*) orientation of the detector in space (two variables); (*b*) distance and direction of the collector from the earth (three variables); (*c*) position of the earth in its orbit. If the distance from the earth is great, (*b*) and (*c*) can be expressed as: (*d*) radial distance from the sun, and (*e*) distance normal to the ecliptic.

If ground experimentation shows that the methods listed above do not depend upon the same function of mass and velocity for the solid particle, the simultaneous use of two or more of the methods may enable the experimenter to separate mass and velocity as independent parameters. For example, if it were proved that sonic methods measure momentum whereas radiation or cratering methods measure energy, two experiments conducted simultaneously might determine both mass and velocity. The above statements emphasize the vital need for ground-based experimentation with ultravelocity particles if space experiments are to be meaningful.

Total velocity vectors of particles in space

It is important to note that, if total velocity vectors of particles can be measured in space, the six spatial and time variables listed above, (*a*), (*b*), and (*c*), can be reduced to four. Any experiment giving the distribution function of mass and total velocity vectors near the earth (say, around the earth's equator for a year) will provide knowledge of the orbits about the sun. These orbits, with other available information on the theory of the orbital changes and lifetimes of particles, will give the distribution of particle masses and total velocity vectors everywhere within 1 astronomical unit of the sun. The mass velocity experiment otherwise needs to be utilized as a function of time and place only to determine the location of meteor streams that do not cross the earth's orbit, and for distances well beyond the earth's orbit where other sources of meteoritic particles may be contributing to the background effects. Extrapolations from the earth to the distance of Mars are probably not very reliable.

No method for obtaining the total velocity vector of a meteoritic particle in space has yet been tested. Time differences to microsecond accuracy are required unless the equipment is awkwardly large; 1 cm/μs corresponds to a velocity of 10 km/sec. A few types of possible methods are listed below with critical comments:

Artificial atmosphere contained in space vehicle—Presumably photoelectric techniques could be used in a long tube for the determination of velocity vectors by methods analogous to those used on the surface of the earth. Unpublished calculations by Hawkins indicate that mercury vapor might not diffuse too rapidly for a practical experiment.

Mechanical shutter at open end of a tube—Excessive velocities are required for a mechanical shutter, even with a rather long tube and millimeter openings in a "sausage grinder" type of shutter.

Rotating drum—This method, suggested by Hawkins, involves an extremely rapid rotating drum with slits to establish direction. It seems to be limited practically by the strength of materials, with possible vibration difficulties as an additional hazard.

Impact in photographic emulsion—Emulsion techniques are probably unsatisfactory because velocity and mass are difficult to separate even with a number of measuring devices; moreover, the method probably requires recovery.

Grid or thin diaphragm at open end of tube—An impact technique may be feasible in which a diaphragm or grid is placed at the bottom of a tube. Detection would be based on ablation at a thin diaphragm or on electromagnetic effects at a grid. The latter method shows promise worthy of detailed study. Hawkins has suggested the use of grids of various sizes to establish dimension and hence density.

Light or radio reflection from particle as it enters tube—A light or UHF radio source might provide the instant of passage across a tube opening, to the required microsecond accuracy for comparison with the impact instant at the end of the tube. The method shows strong promise and should be explored.

Combined methods—A combination of sonic, radiative, and cratering impact methods may be useful, although the interpretation will be complicated and involve much ground-based experimental calibration.

Erosion on exposed surfaces in space

The possible techniques include the following: (1) conducting strip method, developed at the Naval Research Laboratory; (2) thin radioactive strip, suggested by S. F. Singer; (3) transparency of thin film or window; (4) radiation scattering by etched window.

All these erosion methods show promise of successful operation in space, but, as was indicated in the second section of this paper, the erosion rate appears to be so extremely small that such techniques would require long periods of exposure. If erosion occurs primarily from solar corpuscular radiation, a measure-

ment of erosion rates or of average corpuscular radiation near the earth might suffice for all distances from the sun and near the ecliptic plane. On the other hand, if meteoritic dust is largely responsible, erosion measurements should be made at greater distances than that of the earth from the sun.

Charge on solid particles in space

Such measurements would probably operate by means of a grid and field measuring device backed by an impact diaphragm. They would be particularly useful in the study of solar-terrestrial relationships, with regard to variations arising from position in the solar system, conditions in the interplanetary gas, and corpuscular radiation from the sun. The temperature of the interplanetary gas should be derivable from charge measurements.

Composition of meteorites

Possible techniques include the following:

Impacting on low-density material—This method probably always requires recovery; it has been attempted with photographic films by the research group at the University of Iowa.

An artificial atmosphere or impacting substance combined with optical spectrograph—This technique might prove extremely difficult but conceivably could be carried out without recovery.

Zodiacal cloud measurements

Radiation-sensing elements should be used to determine the intensity and polarization of the zodiacal light as a function of wavelength and of direction in space as seen from the neighborhood of the earth. Measurements from other positions in the solar system might be valuable but are not necessarily critical. It is particularly desirable that such measurements be made at wavelengths less than 3000 A.

Study of comets

A space probe passing through the neighborhood of an active comet, near the tail or possibly in the coma, would lead to a number of experiments vital to our understanding of the nature of comets. *A fortiori*, a landing on or a close-up view of the cometary nucleus would be invaluable.

Study of asteroids

A close picture or a landing on an asteroid with proper exploratory equipment would be highly desirable. Research involving landings, by space probes, on near-by comets or asteroids necessitates high space velocities relative to the earth, comparable to those necessary to reach the asteroid belt between Mars and Jupiter.

The physical structure of meteoritic particles

Whether such studies of the physical structure of particles can be made from space is problematical. It will probably be simpler and more economical to study micrometeorites in the earth's atmosphere.

Exploration of the lunar surface

The lunar surface contains a fossil record of meteoritic action on the moon for particles of the entire range from microscopic dust to masses of asteroidal size. Studies of the surface of the moon will provide invaluable information about the impact characteristics of meteoritic material averaged over great intervals of time. More detailed studies will provide additional information about meteoritic material in space; the possible ramifications are so great that no attempt will be made even to list potential methods of attack.

GROUND-BASED METEORITICAL STUDIES

Although research from space vehicles is of great importance in our study of solid bodies in space, I believe that many of the expected results could be obtained from the ground by an effort small in comparison with that of space research. Whether or not the meteoritical observational programs are indeed fostered from ground-based observatories, it is certain that much of the research from space will be of minimal value unless a great effort is made to develop parallel ballistic studies and experiments on the ground. I consider the experiments listed below of critical importance for the future studies of solid bodies in the solar system, whether these studies are to be conducted from space or from ground-based observatories.

Basic meteoritic experiments

Basic ballistics for ultravelocity small particles.—Particle masses of importance here range from 10^{-15} to 10^{-3} gram, with velocities in the range from 1 to 73 km/sec. These experiments are fundamental to an understanding of the nature and phenomena of small particles in space.

(*a*) Calibration of sonic impact measuring devices.

(*b*) Impact radiation measurements. These should be conducted in the spectral regions from the ultraviolet through the optical and infrared, possibly to radio wavelengths. No radio radiation has yet been certainly detected from a meteor.

(*c*) Cratering phenomena. Measurement should be made of crater dimensions, directional dependence, and other crater characteristics as functions of density, composition, and structure of both particle and target.

(*d*) Impact explosion products. Velocity vectors and physical state of explosion debris are required as functions of mass, velocity, shape, composition, and density of particle, and composition and density of target. It is particularly important to simulate possible lunar materials as background for lunar exploration.

(*e*) Tests and calibrations of all types of meteoritical detection methods possibly usable in space with all target materials likely to occur on space vehicles.

(*f*) Erosion effects on all materials of interest as produced by fine, ultravelocity particles.

(*g*) Ballistic trajectory measurements in an atmosphere at reduced pressure and in simulated planetary atmospheres. These experiments should include measurements of radiation, ionization, ablation, and drag as functions of mass and velocity.

Ultravelocity ballistics of larger particles.—Here the methodology is likely to be somewhat different from and more difficult than for experiments listed above for particles in the range from 10^{-3} gram to practical upper limits in mass and for velocities in the range from 1 to 73 km/sec. These ballistic experiments will serve to calibrate both space and ground-based experiments on solid particles in the solar system and will provide critical theories necessary for the interpretation of these observations. The types of experiments visualized are as follows:

(*a*) All terminal ballistic measures possible such as those listed (*a*) to (*g*) above: Target and projectile materials should be varied among the significant substances as regards composition, density, and physical structure. Both vehicular and lunar surfaces should be simulated.

(*b*) Radiation, ionization, and ablation phenomena in a gaseous medium: Such studies represent the re-entry problem and are presumably well covered in other research programs for minimal meteor velocities. Atmospheric densities should be varied, and the composition should be made to simulate the atmospheres of such planets as Mars and Venus.

(*c*) Studies of ablation products in the atmosphere: Here it would be valuable to study the nature of the ablation products left in the atmosphere, including atoms, ions, molecules, and dust particles.

Ballistic studies of dust and larger particles can utilize a number of techniques for acceleration, including acceleration of charged particles in an electric field. shaped-charge explosions, light-gas guns, electromagnetic guns, and multiple-stage rockets. Experiments can be conducted in evacuated ranges, in the open atmosphere, and at high altitude from balloons and rockets. Shock tubes may be extremely valuable for certain phases of the research.

Very few ballistic experiments of the types listed in this section have been conducted at velocities above 5 km/sec. Since the amount of work possible in this area is almost infinite and can be expensive, it is recommended that experiments be aimed largely at establishing basic physical theories applicable in wide ranges of circumstances. Many of the present-day observations would have far more significance were they backed by experiments of the type described above. The importance of such research cannot be overemphasized.

Radio meteor studies

Radio techniques are adequate to determine velocity, vectors, ionization, and atmospheric drag on meteors corresponding to fainter than the 13th visual equivalent magnitude, i.e., to masses less than 10^{-6} gram at meteoric velocities. Only two such projects are under way in the United States, and they are at present severely limited in scope and budget.

Basic radio meteor studies by McKinley and Millman in Canada and by Lovell, Hawkins, and others of the Manchester Radio Group have already been mentioned. These studies have led to extremely valuable findings concerning the orbits and ballistics of naturally occurring meteors in the earth's atmosphere. Such studies, if continued, expanded, and coupled with the ground-based experiments and theoretical studies recommended here, can probably answer most of the questions that could be answered by satellite-borne meteor detectors and, in general, answer them more precisely and definitively. I am firmly convinced of the truth of the above statement except for the possibility of unexpected meteor streams in space and the uncertainty of extrapolation much beyond the range of 1 astronomical unit from the sun.

Radio techniques can determine the spatial-orbit and mass distributions of meteorites striking the earth. With the well determined measures for larger bodies, it will then be possible to calculate orbital changes and lifetimes of particles in space, and predict meteoritic velocity vectors and distributions anywhere within 1 astronomical unit of the sun. As was mentioned before, the extrapolations to greater solar distance will become more and more uncertain with distance.

Furthermore, there are numerous by-products from radio meteor experiments that relate to the geophysics of the high atmosphere, in radio propagation characteristics and in practical forward-scatter communication. Most of the previous radio meteor research in the United States has been aimed at geophysical results and almost none toward the determination of meteoric parameters, phenomena, and physical theory. Exploitation of radio techniques to their limit would reach so nearly the range of particle sizes of interest to space science that other ground-based methods could fill the gap theoretically and leave no major problems on the particle size and velocity distributions for the miscroscopic dust region.

Studies of micrometeorites

I define a micrometeorite as a particle so small (or slow) that it radiates away its energy of interaction with the atmosphere without appreciable damage. Included also in the practical studies will be particles produced from larger meteorites by interaction with the atmosphere, and generally characterized as meteoritic dust. The general subject of micrometeorites and meteoritic dust in the atmosphere, on the ground, and in water-laid deposits is in an exceedingly primitive state, although it has almost unlimited potentialities for giving information about the quantity, chemical composition, and physical states of meteoritic dust particles in space. The audience is referred to the book *Meteoritic Dust* by Buddhue [1950] and to the recent literature. I am not certain that any airborne or surface microscopic particle has been positively identified as of cosmic origin.

Collection of micrometeorites in deep-sea oozes has been largely promoted by Pettersson and Rotschi [1950, 1952], particularly during the IGY [Pettersson, 1958], but much more effort is required to clarify the identification of individual particles and to prove the cosmic nature of the material. Its rate of sedimentation over many parts of the ocean bottom requires further study, particularly in ancient deposits and in the proposed "Mohole."

Collection of meteoritic dust on the surface of the earth and in glacial deposits may or may not yield worth-while results, because of the enormous contamination by terrestrial dust sources. It is quite clear, however, that in the neighborhood of large meteorite falls, particularly of stones, dust collection on the surface of the earth should be intensified. Very fruitful results have been obtained by Rinehart [1958] around the Arizona meteorite crater.

Airborne collection techniques, particularly at extremely high altitudes, show the greatest promise of bringing into the laboratory cosmic material that can be identified as such and studied thoroughly.

Optical microscopes have not yet proved successful for identifying and analyzing micrometeorites. Electron-microscope techniques show great promise in this field, but for some time it will probably be necessary to analyze individual particles by such methods as the electron probe X-ray analyzer under development by Riggs [1956]. Fireman (unpublished) has applied induced radioactivity techniques to small particles but has yet to identify one certainly of cosmic origin. Michrochemical and spectroscopic methods may eventually be useful if particle-collection techniques can provide sufficient samples. Micrometeorites in the air are reputed by Bowen [1953, 1956] to produce sunlight scattering in the twilight sky adequate for measurement. Bowen presents evidence that micro-

meteorites provide condensation nuclei to set off extraordinarily heavy rainfalls on certain dates of the year. The subject of meteoritic dust and rainfall needs much further investigation.

Analysis of individual particles known to be of cosmic origin will lead to a valuable calibration of zodiacal cloud measurements and to calibration of a number of space-based experiments.

Optical meteor studies

Two-camera photographic studies—The Harvard Meteor Program has yielded a number of definitive results with regard to meteoroids large enough to produce visual meteors. As much is now known about orbits of meteors as is known about those of asteroids and comets. Many other facts relating to the physical character of meteorites have been collected. Much more powerful meteor cameras could now be constructed to yield information down to magnitudes of visual equivalent 6 to 8. It is not certain that the gains would justify this extensive and expensive effort. Perhaps a more significant and less expensive undertaking would be the precise photography of very bright meteors (fireballs), as indicated below.

Multicamera fireball photography—This project would involve a network of 9 or more stations separated by distances of approximately 150 km. Each station would cover the entire sky photographically on an automatic basis, so that the velocities, decelerations, luminosities, and orbits of fireballs, detonating bolides, and meteorite falls could be measured. Since there is no strong evidence that the photographed meteors so far include broken-planet debris, the fireball program could bridge the gap between cometary and asteroidal meteoroids. In a few years new meteoritic falls might be discovered in this program, and for the first time precision orbits of meteorites would be known.

The proposed fireball program would produce invaluable information on evolutionary processes, both past and current, among the larger meteoroids, and would provide a better picture of the interplanetary solids in the neighborhood of Mars.

Photographic spectra—Millman [1955], who has carried on basic research on the spectra of meteors for more than two decades, has contributed the major known observational results in this area of research. Such spectra could be interpreted much more thoroughly and precisely on the basis of artificial meteor experiments. It is still not possible to estimate quantitatively the original composition of meteoroids because of the inadequacy of theory and calibration under the circumstances of meteoric light production. The use of dispersive equipment on more powerful meteor cameras would contribute appreciably to our knowledge and is urgently recommended.

Ablation and re-entry studies by photographic meteor methods—Two-camera meteor photography for the determination of decelerations, luminosities, and spectra has long provided the basic data for a theory of re-entry problems. Practical application of the results has been handicapped by our lack of knowledge of the composition and physical structure of meteoroids. However, these studies have shown that the meteoroids of cometary origin are extremely fragile and probably of very low density. Experiments at comparable velocities in evacuated ranges would do much to clarify the nature of meteoroids, and it is possible that the subject cannot progress far from its present condition without such ground-based experiments.

Winds in the upper atmosphere determined by meteor-train observations—considerable amounts of data have been obtained by two-camera photography of persistent trains left behind photographic meteors. The method applies to the range 80- to 120-km altitude, the maximum effect being near 93 km [Liller and Whipple, 1954; Whipple, 1953].

Air density measures by photographic meteor studies—This technique has probably outlived its usefulness in view of the wide variety in the density and physical structure of meteoroids and the consequent low precision of results.

Some 6000 meteors have been doubly photographed in the Harvard Photographic Meteor Program, and analysis is complete for a large fraction of them. If dispersive equipment could be used on the Baker Super-Schmidt meteor cameras, the spectra of fainter meteors could be obtained and considerable progress made. The next step in direct photography appears to lie either in the direction of much more powerful cameras or toward the network of smaller cameras for fireball photography. Considering the few workers active in the field of meteoritics, I favor the fireball network as leading to the most significant results for the least effort.

Optical studies on the zodiacal cloud

The analyses concerning meteoritic dust by optical studies of the zodiacal cloud and the Fraunhofer corona, initiated by van de Hulst [1947] and Allen [1947], are being continued by Elsasser [1958], Haug [1958], and others. Much more study, at all the optical wavelengths available, would be fruitful. At extremely high altitudes these investigations might lead to a definitive determination of variations in brightness with seasonal or with solar activity. Polarzation is a most important factor. In combination with wavelength variations, polarization data might establish more about the physical-chemical structure of meteoritic dust in space and luminosity produced by electron scattering.

Much more experimental and theoretical research is needed to establish the scattering characteristic of the metoroid dust balls and to interpret the zodiacal cloud observations in terms of orbital distribution for the particles.

Meteorites

Only a beginning, hardly more than a taxonomic approach, has been made in the basic study of meteorites by classical methods, including metallurgical, mineralogical, physical, optical, and chemical techniques. It is highly desirable that all these methods, particularly the precision chemical analysis, be applied systematically and thoroughly to the meteorites in our various collections. As Urey [1955, 1956, 1957] and others have shown, meteorites provide a key to our knowledge about the formation of the asteroids and therefore to the planetary system in general. Before using space exploration for the solution of those problems we must make some attempt to exhaust the sound and relatively inexpensive method of study now available for application to meteorites. In this area I cannot overemphazie the significance of a relatively small basic research program to answer fundamental questions about solid material in space and the primary cosmological problems.

Modern techniques in radioactivity and nuclear physics have shown the way to enormous progress in the study of meteorites. Bauer's [1947] evidence for the effects of cosmic rays in producing helium in meteorites has been amply confirmed by the work of Paneth, Reasbeck, and Mayne [1951], Fireman and Schwarzer [1957], Stoenner and Zähringer [1958], and others. Fireman's [1958*a*] work has already led to a measure of the upper limit of erosion on meteorites in Space [Whipple and Fireman, 1959] and has provided measures of the ablation effects of atmospheric passage on two large iron meteorites [Fireman, 1958*b* [1959]. These methods, if thoroughly exploited, can lead to many unanticipated results with regard to the effects of cosmic rays on bodies in deep space, the nature and origin of meteorites, and other problems of great practical and theoretical interest. This fresh, new method of attack appears to be of extreme value and potentiality. Its exploitation should be accelerated.

Studies of meteorite craters

Very little progress has been made on the subject of great impact crater formation on the earth, except for the final acceptance of Barringer's [1905] interpretation of the Arizona meteor crater, and the general recognition by geologists of a few structures of meteoritic impact origin. Recently Beals [1957] has done outstanding work in identifying geologically covered and eroded craters in Canada, and has added materially to our understanding of the nature of such structures. Research on these huge craters, however, is still in its infancy and should be encouraged. Not only do such studies clarify the problems of crater formation by huge explosions but they also give us ancient historical information of geologic value as well as an insight into the occurrence of large, solid particles in space during geological history.

It seems premature to make intensive studies of craters formed on the moon before we have thoroughly investigated those available locally on the earth. Thus far, only little research has been done on the great craters in the United States.

Current research by astrophysical methods

Increased observational and theoretical studies of comets are clearly indicated if we are to understand the occurrence of small particles in space, since the photographic meteor studies show clearly that comets are the major contributors to meteoritic dust. Much valuable research on comets can be conducted with the aid of modern auxiliary equipment in conjunction with astronomical telescopes.

Studies of asteroids by astrophysical methods

Most of the physical studies of asteroids since 1950 have been conducted by Kuiper and others [1958]. Continued studies of these bodies should provide results of high significance to space probes, particularly in the range of the solar system between Mars and Jupiter.

Perturbation studies of the motions of astronomical bodies

Many more theoretical studies are required to understand the origin of comets, the variations in their orbits produced by the perturbations of the planets, and the changes in the orbits of smaller bodies caused by perturbations, by solar radiation, and by interplanetary gases. Many of the developments required for the solution of the problems of comets, asteroids, and interplanetary particles will lead to techniques and results significant in space research. It is to be hoped that modern methods of analysis and computing can be used much more extensively in these various basic problems of celestial mechanics than they have in the past.

I am especially grateful to G. S. Hawkins, L. G. Jacchia, and R. E. McCrosky for discussions and suggestions that have added materially to this paper. G. K. Wehner has been most generous in permitting me to publish his tentative results on the sputtering rates of protons on iron.

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DISCUSSION

Question: You mentioned the desirability of a further study of meteor craters on the earth. Several years ago, an article was published on the sighting of meteor craters from the air. I wonder if such a survey has been continued.

Mr. Whipple: I don't think that has been done consistently. You must in any case follow up with studies on the ground by drilling, measuring gravity anomalies, magnetic anomalies, and actually getting into the rubble defining the crater.

Question: Dr. Whipple, you mentioned that the two-camera technique was perhaps near the end of its usefulness. Still, the two-camera data which you obtained are the only quantitative data we have on meteor entry into the atmosphere. Therefore, I am interested in your statement that you have measured 6000 of these in the last few years. Are these data being reduced, and will they be available?

Mr. Whipple: There are three programs in that area. Dr. Jacchia has done about 500 of the longest and most precise tracks. Dr. Hawkins has studied 400 randomly selected cases, mostly shorter ones. And McCrosky has studied 2500, taking everything that was measurable out of the 6000. Those data are being prepared for publication now.

Mr. BROOKS. Thank you very much, Dr. Whipple.

Now, our third speaker today is Dr. Revelle. Dr. Revelle won't be here tomorrow. We want to get to him today.

Now, Mr. Anfuso.

Mr. ANFUSO. I would like to ask Dr. Whipple what is being done on an international level with respect to earthquakes?

Dr. WHIPPLE. I am not well enough informed to give you a proper answer on that, because as a part of the International Geophysical Year and then the International Geophysical Cooperation, there is a certain amount being done, but it is not a high level of support in terms of any heavy research program. That I am sure.

Mr. ANFUSO. Do you regard it important enough to warrant deep study?

Dr. WHIPPLE. Yes. I think it is an extremely important aspect of Earth studies, where we have only put in great effort so far for a very specific need, such as oil prospecting. For that very limited research, limited goal, there has been a lot of study, but the broad, deep scientific study has not been pursued heavily. The nuclear test aspect is vital.

Mr. BROOKS. Doctor, along that line this committee has, and the Congress, and the country, too, a number of important programs, such as weather research and high energy physics, and many other programs. It seems to me, though, there is danger that one program for the moment may push out another program.

Now, what we need, really, is some balance to measure the need of one program as against another program so that financially, for instance, the Government might give the proper support to the most important programs.

Do you have any thoughts along that line?

Dr. WHIPPLE. I do have, but it is too long, too difficult to express them quickly, because this is a case of very careful balancing, with a given amount of funding possible, to support to the greatest advantage the various endeavors, scientifically and technologically, that are essential.

I don't think I can generalize in a few words.

Mr. BROOKS. That is something this committee might look into in a more detailed way in the future; isn't it?

Dr. WHIPPLE. Yes.

I think perhaps the point of view that you might carry is how best to exercise judgment, scientifically and technologically; how should the judgment be applied to assist you and assist everyone who has the responsibility for funds.

Mr. BROOKS. Mr. Hechler.

COMMENTS BY REPRESENTATIVE HECHLER

Mr. HECHLER. Do you get the impression sometimes that NASA is so much under the gun to produce and to meet immediate deadlines and produce certain concrete results, that they don't have enough individuals there who are charged with the responsibility of thinking and coordinating and planning, particularly in relation to the university research?

Dr. WHIPPLE. I think this is true and in no sense a criticism; I think it is just one of these inevitable situations that has developed in which a new group is built up very rapidly and in which they just have not had time to do all of the things that need to be done.

Mr. HECHLER. Now, I want to ask you specifically about your first point on investigation of the nature of the lunar surface.

If this could be done at 1 percent of the cost of the lunar probe, does this indicate that if NASA appreciated this, NASA could not undertake this type of research directly, itself?

Dr. WHIPPLE. It seems to me they might. I am not saying that the lunar probe would not be as essential as ever; it would simply be more effective if you had this study ahead of time.

Mr. HECHLER. I see.

Mr. BROOKS. Mr. Goland?

Dr. Martin Goland, president of the Southwest Research Institute of San Antonio, Tex.

Mr. GOLAND. Thank you, Mr. Chairman.

After your remarks earlier today, and my being about the only "mister" on this panel, I anticipate I ought to keep quiet. But I do appreciate your elevating me to "doctor" for the present purpose.

Mr. BROOKS. I will refer to you in the future as President Goland.

Mr. MILLER. You now qualify for Congress. [Laughter.]

REMARKS BY MARTIN GOLAND

Mr. GOLAND. Mr. Chairman, I would like to make a few remarks, very briefly. First, there has been a thread running through the remarks of the members of the panel, starting with the last meeting and continuing here—Dr. Russell's remarks in regard to the need for some new kind of overall research planning, of which perhaps the National Research Institute is one possibility—this type of thinking has continually recurred.

National Research planning

I would like to suggest, if I may, Mr. Chairman, that if the members of the panel are permitted to put items on the agenda, that it

might well be worthwhile to concentrate at one of our meetings on just this question of national research planning.

It seems to me that there has been a curiously passive stand taken by many of those who direct our overall research effort. I am not implying criticism of certain individuals, but perhaps of the entire research community itself.

Nevertheless, there has been a curiously passive planning attitude toward how we spend our research dollar to bring the best results.

Everyone will agree, for example, that the role of the individual researcher in the university should not be affected. Everyone will agree that industrial research with its team effort, its directed objectives, is an extremely powerful technological part of the picture.

But there are other needs as well, possibly the National Institute concept, in order to approach optimum research effectiveness over the entire spectrum of national effort. I would like to suggest, Mr. Chairman, that this question be considered. It has occurred in just about every presentation given by one of our panel members. I think it is worthy of considerably more thought.

Man in space

Now, I certainly do think that Dr. Russell's talk was most excellent and certainly Dr. Whipple's also. I would, however, like to make one remark about this robot in space which continually comes up, and I think the best I can do is simply repeat a remark made by Dr. von Braun some time ago, that if we send a robot in space or if we send instruments into space, what we get back is a telemetered record. When we send a man up, he comes back and writes a book about his experiences—and I think that very cogently puts the point.

I have not as much confidence in television as a recording medium as Dr. Whipple does, and I would hate to see any implication that Project Mercury and the man in space is not of extreme importance and very great urgency.

I know, incidentally, that any such implication is certainly not what Dr. Whipple intended, but I merely wanted to emphasize that point.

National Aeronautics and Space Administration

The last remark I would like to make is in regard to the NASA program.

Dr. Whipple has been one of the most valued members of a very elaborate system of research advisory committees set up by the NASA, and I have also been fortunate enough to be in that program under the old NACA and now under the NASA.

I believe we should not underestimate the very great striving within the NASA to accomplish research planning. And they are not only doing this with their own staff and their own personnel, but through the extremely elaborate committee system, which calls into play the very best brains in the country, present speaker of course being excepted.

There is a great striving for planned research. If some of their recent efforts have been less than successful, it is perhaps because they have felt an obligation to accomplish some very direct things very quickly; tremendous demands have been placed on them which

they cannot completely meet, either in terms of finances or in terms of available personnel.

I do think, however, that we should acknowledge the fact that they are sincerely looking at the broad front and that certainly they have laid a groundwork to do so.

Thank you, sir.

Mr. BROOKS. Dr. Whipple, do you wish to comment in reference to the remarks?

RESPONSE BY DR. WHIPPLE

Dr. WHIPPLE. Only one word that I certainly agree in principle with the comments that Mr. Goland has made, and only add that I think quite a bit of this reaction that I have expressed, and many of my friends in science have expressed, results from a new situation. All of a sudden we see really huge sums of money being expended, for pure science and engineering, for national welfare with longer term goals. We immediately think in reference to our scientific lifetimes in which to get a thousand dollars for a piece of equipment was a major effort in a university. I think that many feel we have not yet gotten a proper balance between the very careful and deliberate sound research, with minimum budgets, and the huge potentialities of a nation which now realizes that its future is so dependent upon this research that it puts extremely large sums of money into it.

It is this balance that worries, I think, a great many scientists. I have had many private conversations on this subject, and you will find articles written about it.

Mr. BROOKS. I suggest that we get into that further tomorrow, or this afternoon in our breakdown discussions of the problems that we have.

Dr. Whipple, we certainly appreciate the very fine statement from you.

Dr. WHIPPLE. Thank you for the opportunity, sir.

Mr. BROOKS. You always make an excellent statement.

The next speaker that we have this morning is Dr. Roger Revelle, who was abroad the last time we held our meeting of the panel in Washington. He is director of the Scripps Institution of Oceanography, a branch of the University of California.

Recently this committee made a brief study of the ocean sciences. One of the topics which there was not time to explore was the problem of international cooperation in this area. Therefore it is particularly appropriate that Dr. Revelle addresses himself to this subject today.

Dr. Revelle, we are very happy to have you here for the first time, sir.

Dr. REVELLE. Thank you very much.

PAPER BY DR. ROGER REVELLE

Mr. Chairman and members of the committee, I would like to depart briefly from what I was going to say to discuss two aspects of the questions that Dr. Whipple and members of the committee were just talking about.

Seismology and nuclear testing

One, about seismology: This is an interesting and perhaps tragic example of how the neglect of one field of science may, over the next 20 years or so, vitally affect the future of mankind.

As you know, the negotiations at Geneva about the possible cessation of atomic tests, which were stimulated largely by the fear on the part of both the United States and the U.S.S.R. and the British, that many nations might independently develop atomic weapons, and that this would lead to a completely unstable situation, rested very largely on the belief among many American scientists that underground tests could be detected.

The reason they thought this was that some of the seismologists said they could do it. It turned out on further investigation that the detection of underground tests with present seismic methods is very difficult.

I am convinced, after having been involved, indirectly, with the considerations of these matters, that it would be quite possible to develop seismic methods of recording and analysis which will make it possible to detect underground explosions and particularly to distinguish them from earthquakes.

But this would only come about if we completely and fundamentally change the methods of recording and analysis of the wiggles of the Earth, the vibrations or the unrest in the Earth, and use modern methods of high-speed computation for data handling.

What is really needed in seismology is a major effort, not by the old-fashioned seismologists—you could give them a lot more money without really affecting very much the level of the science. What is really needed is a major effort by physicists and mathematicians, armed with the most modern tools of computation, to really see what you can get out of the records.

A great deal more can be gotten out of the records than the seismologists are now able to obtain, simply because of the rather specialized and rather traditional methods that they use.

Mr. Brooks. Could I interrupt you there and say: for instance, in these earthquakes we are having down in Chile now, would it be possible, or could we approach the time when it might be possible to anticipate those to the point that we might save human life and destruction of property, too?

Dr. Revelle. This I would not be willing to predict, Mr. Chairman. I don't think anybody at the present time knows enough about it.

In general, many geophysical phenomena are very difficult to predict. There is a saying that the meteorologists use which is appropriate here: "A storm off the west coast of North America may very well originate because somebody sneezes in China."

Nobody knows whether this is really so or not, but if it is so, then there are very definite limitations on prediction. This may also be true of earthquakes.

Mr. Brooks. Somebody had a big sneeze down there in Chile.

Dr. Revelle. In other words, you may have very small causes which produce very large effects, and these are very hard to predict.

But this other problem of the detection of atomic tests, we undoubtedly will be able to make great pprogress now that some money and some attention is being paid to the problem. But it will probably

be too late to really prevent the catastrophe which hangs over mankind of a widespread development of atomic weapons.

And this can be laid directly to the fact that seismology was a neglected science by the scientists themselves, and particularly by the basic scientists, the physicists and chemists.

I am not sure that I know exactly what to do about this, except that it emphasizes that science must—the scientists must somehow stick together and help each other and they must be encouraged to do so by the Government.

Research and graduate teaching

The second remark that is not quite pertinent to my prepared statement is about the planning of science in the U.S.S.R., in the Soviet Union. This is something I have been very much involved with lately for the President's Scientific Advisory Committee.

The Russians, as you all are aware, lay great store by planning; planning is an essential tool of the Communist Party and the Communist apparatus. And they have tried to plan research on a very large scale.

They have lately made a marked turnabout in the way they attempt to do research. They are trying to combine much more closely research and graduate teaching, to give much more responsibility to the universities and to have the research institutes more intimately associated with the universities, and the basic reason for doing this is because of their feeling, which I think most of the members of this panel will share, that basic research and what you call graduate education are almost a redundancy, that you can use these four words in any order you want and any two of them will do, that they are essentially the same thing; that the teaching of young people and their apprenticeship in research is essential for good research. And of course it is also essential to produce the research workers upon whom the fate of the Nation depends.

We will undoubtedly be able to go further with this this afternoon.

Interrelation of the Earth sciences and space sciences

Now, coming to the topic that I am supposed to talk about. Dr. Russell and Mr. Miller and Dr. Whipple have all emphasized this morning the need for understanding the Earth.

It is an ironic fact that just as men are achieving the ability to leave the Earth, they are beginning to realize that they had better understand it; that the Earth is our planetary home.

As far as I am personally concerned, I take a very dim view of those people who say it would be better to spend more money in studying the Earth and less money in studying outer space.

I think that the basic premise upon which we must operate is that men must do everything they can do, and one of the things we are now able to do is to leave the Earth and to make voyages into the dark night of outer space.

But at the same time, no matter how far we penetrate into the distant reaches of the galaxy, we must remember that we are the creatures of the Earth, that the Earth is our home, and that it is only by learning how to use the Earth wisely and well that we will be able to develop or to maintain and to develop a decent life for human beings,

particularly under the pressure of the enormous increases in human populations which are now occurring.

Interestingly enough, as has been pointed out by Dr. Whipple, the study of space and the study of the Earth go hand in hand. We can learn a lot about our planet by studying the other planets of the Solar System. But one thing that is quite essential here is to study the Earth as a whole, not to study it in bits and pieces.

This of course was a realization that we came to during the International Geophysical Year, which caught the imagination of all mankind. I would like to give one or two examples.

In the first place, the phenomena that take place in the air, weather and climate, which really control agriculture, living conditions, the possibilities of using parts of the Earth which we do not now utilize, these phenomena depend upon a very intimate set of processes between the air and the oceans, and also an intimate relationship between the atmosphere and the Sun, itself.

In order to study the atmosphere effectively, we have to know a great deal about what the Sun is doing, not only the light that comes from the Sun, but the particles that come from the Sun, and the effects of these charged particles on the magnetic and electromagnetic phenomena in the outer layers of the atmosphere.

In fact, I would like to define the atmosphere, if I had "my druthers," as that mass of matter which lies between the surface of the Earth and the surface of the Sun.

As far as the air and the ocean are concerned, nearly all the energy that drives the winds and that produces storms and produces the rain comes from the Sun by way of the ocean. The energy penetrates into the ocean and then gets back into the atmosphere, first by the evaporation of water, and then the subsequent condensation of that water and the release of sensible heat into the air.

The Earth as a whole

Dr. Russell talked about the needs of geology. Here again, the basic problem at the present time in my opinion is to understand the Earth as a whole.

All of the phenomena which take place on the surface are intimately related to what happens deep within the interior of the Earth. We can say this simply by saying that the Earth is alive in the interior.

Dr. Russell, for example, pointed out the fact that different parts of California are moving with respect to each other. This is even more obvious underneath the Pacific Ocean where there are a series of great plates of the sea floor which we can show quite conclusively have moved past each other over an unknown time by distances at least as much as 250 miles.

We were speaking about the recent earthquakes off Chile. Actually, these tragic earthquakes represent only one small part of a worldwide phenomenon, or a phenomenon of world scale. This is the ring of earthquake epicenters which stretches all the way around the Pacific, and which is paralleled by a ring of fire, a ring of volcanoes.

It is also a ring of great gashes or trenches in the bottom of the ocean, long, narrow trenches thousands of miles long and tens of thousands of feet deep, the deepest ones—four of them all about the same depth, all about 35,000 feet deep.

These phenomena—the trenches, the earthquakes and the volcanoes—must all be very closely related to each other, and they must be related in a way that we don't understand to what is happening far beneath the surface of the Earth, in the deep interior of the Earth.

The source of the energy, we believe, which is responsible for all these phenomena is the decay of radioactive materials in the interior of the Earth. In some sense, you can say that the Earth is a gigantic reactor, a gigantic atomic plant, which is producing energy by radioactive decay.

We haven't really the least idea what rocks are deep beneath the surface of the Earth. All of our fundamental geological dogmas or doctrines are, I think, highly questionable; for example, the doctrine that the continents have existed and oceans have existed throughout most of geologic time is just an article of faith; the evidence to support it is very meager.

We just have to find out somehow what the interior of the Earth is made of. The best place to do this is under the ocean, and there is right now a plan supported by the National Science Foundation and sponsored by the National Academy of Science, actually to drill deep within the Earth under the ocean to try to get samples of the rocks that make up the Earth's interior, which will throw great light on all of these problems of geological activity and geologic history of the Earth.

The ocean, of course, is important to us in a variety of ways, not only because it conceals most of the geologic history of the Earth and stretches over most of the Earth and because of the intimate relationship—the completely inseparable nature of the Earth and the air—but also because the ocean represents a very great source of protein food.

Peruvian fisheries

I can cite one quite dramatic example of the development of the potentialities of the harvest of the sea off Peru. Peru, which 3 years ago was a negligible fishing nation, has now become the second largest fishing nation on Earth, producing something between 2 and 3 million tons of fish this year. This represents the development of a resource which has long been suspected to exist; very large populations of very small fish: the anchovettas and other sardinelike fishes that live off that coast.

This Peruvian region is perhaps the most fertile region on Earth, either in the land or in the sea. The essential thing about the oceans is (*a*) that they are so large and so alien to human life that it is very difficult to find out about them, and (*b*) no one nation can find out all it needs to know about the ocean, because in order to understand any one part of it you have to know quite a bit about all parts of it.

Need for international cooperation

So the study of the oceans in all its complexity, thinking about the interior of the Earth beneath the sea, about the relationships between the air and the ocean—the ocean, that is, and the air above the sea, the ocean of air and the ocean of water—the essential thing in my opinion is that here is an area where international cooperation is not only desirable but absolutely essential.

This need for international cooperation in the study of the oceans is gradually being recognized, and this summer in Copenhagen there is going to be an intergovernmental conference, at which the chief of our delegation will be the Assistant Secretary of the Navy, Dr. Wakelin, and there will be people of his governmental level representing the other countries. It is going to be a conference to try to determine what can be done internationally to increase our knowledge of the oceans.

One of the important outcomes of this conference, I hope, will be the establishment of an international intergovernmental commission of all those nations which want to study the ocean and are capable of studying the ocean, so that they can arrive at methods, means of exchanging results, to some extent dividing up the areas that each nation will study or kinds of work that each nation will do, so that on an international basis as much of the scientific and engineering and technical work at sea can be coordinated as is possible to do so.

One of the primary problems, of course, is the exchange of information, to make sure that we produce a lot of information about the oceans, and if the Russians produce as they are now producing also a great deal of information, that this information will be exchanged and it will be of maximum usefulness to both countries.

Here, we are operating, I hope, in a more enlightened and sensible way than the oil companies, which have always maintained a security in their investigations of the Earth, so that half a dozen oil companies very often make a geologic map and seismic investigation of the same area. Actually, the oil companies would have profited in most cases if they pooled their scientific efforts and then used these results for their individual needs and operations.

The same thing is certainly true of the oceans. I am convinced it will be a great deal better if we work with the Russians and the British and the French and the Germans and the Scandinavians, than if we all try to do this job independently. In fact, we just can't do it independently. The job, with the present resources in men and ships, not necessarily in money, is just too great.

Indian Ocean expedition

As a specific example of international cooperation which is now being planned, I would like to describe a joint expedition which is being sent to the Indian Ocean.

This is being sponsored by the International Council of Scientific Unions and by UNESCO, and each nation that takes part will provide its own ships and its own men, but the hope is that young people from around the Indian Ocean, in the countries bordering on the Indian Ocean, will also be able to take part.

This is an expedition which will continue for the next 4 years, some 16 ships from 11 different countries: Russia, Japan, France, the United Kingdom, United States, Australia, South Africa, India, Pakistan, probably also Germany, will all take part in it.

The Indian Ocean is an area which covers about 14 percent of the surface of the Earth. It is about 20 percent of the surface of the ocean. In some sense it is a kind of a model of the entire ocean because it is enclosed on the north, it is a little world ocean in itself.

1. Food supply.—Something like a quarter of all the people on the Earth live on the borders of the Indian Ocean. One thing that you

can say about these people is that on the average they never get enough to eat, and particularly they never get enough protein to eat.

It is possible, there is some evidence, some good reason to believe that the potential harvest of the sea in the Indian Ocean is very great, but nobody knows whether this is so or not.

This is one of the objectives of this international expedition, to see whether, in fact, the fertility of the ocean is sufficient to maintain or to develop a very much larger fishery.

2. Relation to weather.—Another objective, and a very interesting objective scientifically is this: I have spoken about the very close relationship between the ocean and the atmosphere, the fact that the energy from the Sun goes into the ocean and out again.

On the other hand, the movements of the ocean waters and the circulation of the waters are pretty much at the mercy of the atmosphere.

Oceanographers often say that the ocean is the slave of the atmosphere—referring, of course, to the currents in the ocean—in the case of the Indian Ocean. And we have winds that alternate in direction between summer and winter, the northeast monsoon and the southwest monsoon, and we are sure that these winds which completely change seasonally also must have a very profound effect on the changes of the currents.

Here we have an example or possibility of conducting a kind of experiment to see just how the wind drives the ocean. We know that in general it does, but we don't know the mechanism by which it happens. And by studying what scientists call the transient state, that is, the changing conditions, it is possible that we will gain very great insight into the detailed processes by which the winds drive the ocean currents.

3. Structure of the Earth.—Still a third problem in the Indian Ocean is the problem of the shape and structure of the bottom, and what it can tell us about the interior of the Earth.

The largest features on the Earth's surface, next to the continents and oceans themselves, are the great ridges that lie in the middle of the Atlantic Ocean, the so-called Mid-Atlantic Ridge, the ridge that lies in the middle of the South Pacific, which is often called the South Pacific Rise, or the Albatross Plateau. These two ridges go together in the Indian Ocean and run into each other in a knot, in a complex structure.

We hope by studying in detail what this knot-like structure is like that we will gain considerable insight into the nature of these ridges, what they mean for the history of the Earth, and how they are being formed, and what is happening to them.

4. Costs and benefits.—The costs of this expedition which is in a sense a little International Geophysical Year, and is of course a successor to the International Geophysical Year, the overall cost will probably be of the order of $20 to $25 million. Of this amount the United States' share will probably be around $7 million.

Most of this will be simply the normal expenditures of the major oceanographic institutions, the Scripps Institution, Woods Hole Oceanographic Institution, and the Lamont Geologic Observatory.

There will, however, be some extraordinary costs probably in the order of a million dollars a year for the next 4 years. And this prob-

lem, or this plan, this proposal for the United States to participate and indeed to take the lead in this international Indian Ocean expedition, has been considered by the Federal Council for Science and Technology, and has been endorsed by them and the National Science Foundation will take the responsibility for the financing. When I say they will take the responsibility, what I really mean is that they will come to Congress and say to you that they need this $1 million a year for the next 4 years. So you can expect them—I think you can expect them to present the detailed justifications.

The principal political or social benefit that I think we can think of as coming from this, as far as the United States is concerned, is that here we have a chance to, in quite an inexpensive but in a very fundamental and long-range way, to give technical and scientific assistance to the peoples of India and Pakistan, the peoples of East Africa, and Indonesia, in helping them to develop a rather simple kind of science, a science which is however of great practical benefit to them. And also to essentially show the flag, show the U.S. flag in this vast ocean area with its teeming populations around its borders, not in a military way, but in a scientific, international, cooperative way, which all who have been concerned with it believe will have a very profound effect in quite intangible ways on our relations with these countries.

I will be glad to answer any questions.

CONCLUDING REMARKS BY THE CHAIRMAN

Mr. BROOKS. Doctor, we certainly appreciate your very profound statement in reference to oceanic problems that we have in this world of ours.

I would say this, however, it is 5 after 12 now and our colleague, Mr. Mitchell, who has chairmaned the Subcommittee on Patent Laws, has an hour's time on the floor this afternoon, and he is going to discuss our bill that comes up next week. It will probably be Wednesday of next week.

Some of the members of the committee, I know, want to be present at the time he discusses it, and to participate in the discussion, so I would suggest this: We are going to meet in the morning. This afternoon the committee room here will be open and free for use. Our staff will be available, and as I say, a good many of the members, maybe all of us would be on the floor to hear Mr. Mitchell and take part.

Therefore we can reserve our questions, Doctor, and there will be questions, I am sure, to ask you, until tomorrow morning at the discussion then.

If there is no objection, because of these facts, we should adjourn, and we will stand adjourned until tomorrow morning at 10 o'clock.

Dr. Sheldon, will you see that everything is available for these distinguished guests of ours, and that they do have an opportunity to participate in any discussions that the staff may wish to bring up?

We will adjourn until 10 o'clock tomorrow.

(Whereupon, at 12:06 p.m., the meeting adjourned, to reconvene at 10 a.m., Friday, June 3, 1960.)

SECOND FORMAL SESSION OF THE PANEL ON SCIENCE AND TECHNOLOGY

FRIDAY, JUNE 3, 1960

COMMITTEE HEARING ROOM (214B),
New House Office Building, Washington, D.C.

The meeting convened at 10 a.m., Hon. Overton Brooks presiding.

OPENING REMARKS BY THE CHAIRMAN

Mr. BROOKS. The meeting will come to order.

If you gentlemen will come forward here. Dr. Van Allen, we will put you right here. The members will be in later.

Off the record.

(Discussion off the record.)

Mr. BROOKS. On the record.

This morning we have three real treats for the members of the committee. We have Dr. W. Albert Noyes, Jr., professor of chemistry of the University of Rochester, New York. Dr. Noyes has just come back from Russia.

He does not have a prepared statement; is that correct, Dr. Sheldon?

Dr. SHELDON. Yes, sir.

Mr. BROOKS. Since he has no prepared statement, being fresh from Russia, I think it would be appropriate if we call on Dr. Noyes first this morning.

Dr. NOYES. Mr. Chairman.

Mr. BROOKS. Would you rather get there at the microphone? I think it would be preferable because perhaps some of these newspapermen would like to hear what you have to say.

Dr. NOYES. I had better be careful, perhaps, of what I have to say.

Mr. BROOKS. Dr. Noyes.

SOVIET TRIP REPORT BY DR. W. ALBERT NOYES, JR.

Dr. NOYES. Mr. Chairman, my trip to Russia was 9 days in Russia, that is 11 days from portal to portal, you might say. I have always been suspicious of people like André Maurois, who visited the United States for a week and wrote a book on the United States.

So you will have to admit that a person who doesn't know the Russian language and who was there such a short time might make very superficial observations which would need to be checked by other people.

My purpose in visiting the U.S.S.R. was to attend a meeting of the executive committee, what is called the Bureau, of the International Union of Pure and Applied Chemistry, in Leningrad.

Following that, we were invited by the Soviet Academy of Science to visit Moscow. Unfortunately, this is the time of year when examinations are held and I couldn't stay the full time we were invited to stay in Moscow. I had only 3½ days there.

Visit to Leningrad

I came in via Helsinki, directly to Leningrad in a small plane that looks like a DC–3. There were so many people that they had to run it in two sections. It normally only runs twice a week, and the plane I happened to be on was full of American tourists.

I think there were only about 2 people out of the 18 on the plane who weren't Americans. I am sure that most of them weren't on official business, they were just touring around. There were nice, elderly men and their wives, the kind of people who have retired and just want to see the world. This is the way they acted and I am sure this is what they were.

During the time in Leningrad, we were mostly in committee meetings, but I can give you a few personal remarks.

In the first place, we were met at the airport in Leningrad by a member of the Soviet Academy. There was no baggage inspection, we went rapidly through customs and immigration, and we were treated, in other words, as honored guests.

There was no evident hostility on the part of the hotel employees or the man in the street. They were curious about the States, and boys, as always, who stop you to ask you for chewing gum.

Effects of the U–2 incident

Mr. Brooks. May I ask you, was that before or after the U–2 incident?

Dr. Noyes. This was after, immediately after. In fact, I just left Moscow last Monday afternoon. So it was all after, and in spite of that, when you would smile at a Russian he would smile back.

There were a few incidents which indicated that the scientists may be somewhat worried about the situation. One young man, for example, has applied to come over here for a year of study. And he said: "Well, in view of recent incidents I am afraid I may not be able to come, but I am sorry for this because I very much want to visit the United States for a year."

There was one professor whom I met in Paris, actually 3 years ago, in Leningrad, and I asked him whether he was coming to the United States and whether he might not give us a lecture on what he was doing. He is an eminent authority in his field.

He said: "A few weeks ago, beyond question I would have said yes. Now we will say, let's see what develops; I am not sure I will be able to come."

This indicates not so much an antagonism which has resulted from the U–2, as an uncertainty as to what the relationships between the Russian scientists and ours are going to be in the months to come.

But I can say I think beyond question that there was no open antagonism, but rather still the real curiosity on which many people commented. They would stop you on the street and ask you why you were there. Since I don't talk Russian, we would have to find a common language. I can handle French and English and German up to

a point. And a surprising number of them talked German, so this is the language I know least well but the one we most often used.

I visited, also, the circus, last Saturday night. Scientists have to amuse themselves as best they can at times. One of the clowns was playing around while the scenery was being changed. Suddenly he stopped and looked up in the sky and while I can't understand Russian I can understand "Amerikanski" [laughter], and there was something up there which was American and obviously a plane, and then there was a big bang and some junk fell on the floor and everybody laughed. So apparently, at least some of them can treat the U–2 incident with a sense of humor still.

Mr. BROOKS. This wasn't a U–2, was it?

Dr. NOYES. I think it was supposed to be. I couldn't understand Russian but it was something American up in the sky anyway that came down. [Laughter.]

Anyway, as far as the scientific laboratories are concerned I saw only two, really. One was the laboratory that deals with plastics, viruses, large molecules, in Leningrad. It is housed in the old administration building used by the czarist government for customs administration. The floor is uneven, the walls are unpainted, it looks awful, and yet inside there are beautiful instruments and they seem to have no dearth of these. They apparently have all the money they need to buy scientific instruments.

The people to whom we talked, I think, were the people they wanted us to see, but they did seem enthusiastic about their work. They knew what they were doing, and I had the impression that they were exceedingly well trained.

Laboratory of chemical physics in Moscow

Now the laboratory I most wanted to see in Russia was the laboratory of chemical physics in Moscow. I put in a request for this and I did see it, and as far as I can tell there were no strings on what I saw.

I did know two or three of the people already. I had met them in Paris in previous visits, and we had a really delightful morning talking just science. There was no political implication as to what we were talking about. The director has the Nobel Prize and others are also extremely competent people.

It is an outstanding laboratory, perhaps one of the best in its field in the world.

That was Saturday, and if you remember Khrushchev gave a speech on Saturday. It was one of his major speeches in the last few weeks. The head of the laboratory had to go to hear Khrushchev, so he asked me to come back to his office on Monday morning.

Well, about 8 o'clock Monday morning as I was going down to breakfast at the hotel, I got a telephone call saying that Professor Seminov and his wife expected me for breakfast. They sent a car for me and I went to his home.

Well, he said this is a special occasion. So he pulled out a bottle of wine before breakfast and said we had to drink a few toasts. This is a tough way for an American to begin breakfast, I can assure you. [Laughter.]

But it was very pleasant.

Well, I had about an hour there in his home. It is over his laboratory, overlooks the city of Moscow with a beautiful view.

University of Moscow

Then I went to the university, which is a skyscraper. Most Americans think this is the University of Moscow, but it is only the scientific part of the University of Moscow. The social sciences and humanities are relegated to the old buildings downtown that were built at least two centuries ago. But the scientific part of the university is this magnificent skyscraper, 32 stories high, surrounded by institutes.

They have about 15,000 students in the University of Moscow, divided into 11 different faculties. About two-thirds of them are in science. Their standards are high.

Just in wandering around the hall you see students from many other countries, particularly Arabs, people from north Africa, and people also from south Asia.

So I think we Americans need to face the fact that in many ways Moscow is becoming the intellectual center for the peoples of some of these underdeveloped countries. It is a thing to which we need to give attention in our thinking in the next few years, or for the long-range future we may suffer as a consequence. We have got to be sure that at least our share of these people look toward us and not toward that country for their leadership in the intellectual things of life.

Mr. BASS. Did you see any Chinese students there?

Dr. NOYES. Lots of Chinese students were around.

Also, you might be interested to note that in the hotels now these little notices that tell you not to leave your valuables around and all this kind of thing that are customary in hotels are given in Russian, French, German, and Chinese.

They put that on a par with the other three languages in the hotel.

Well, I think I have talked much more than the 10 minutes which I promised to talk. I ought to stop. I will just conclude then by saying that there was no outward, open antagonism toward Americans, a curiosity, rather a feeling that they didn't want war. One must remember that the city of Leningrad was under siege for 900 days, 600,000 people there died of starvation during these 900 days, that they don't particularly love the Germans in that city and while I didn't become pro-Soviet over there I think one should remember that they did suffer during the war and that they don't want war repeated. The man in the street I think makes this evident when he talks to you.

Thank you, Mr. Chairman.

Mr. BROOKS. May we ask you just a few questions?

Dr. NOYES. You can ask me anything you want. I may not be able to answer.

SOVIET ATTITUDE TOWARD AMERICANS

Mr. BROOKS. You feel that whatever antagonism there may be is in official life rather than among the people?

Dr. NOYES. I would suspect that it is high up and I am not sure orders haven't gone out to treat Americans well. I believe they expect about 60,000 tourists who will spend some money over there.

There is one minor incident: On the tables in the restaurant of the Astoria Hotel in Leningrad they had flags of several nations, Soviet flag, American flag, or French flag on each of these tables. A French and Swiss friend of mine sat down at a table where the American flag happened to be. They thought they might get a little better service if they moved this flag over to another table. The waiter came over and said, "Nyet, nyet, we want this flag over here." They apparently were under orders to keep the flag where it was.

Mr. BROOKS. You think they have orders from some high position to treat Americans with due decorum and courtesy?

Dr. NOYES. I would say this is probably true in the hotels and restaurants, but I don't see how this could have filtered to some of the people on the street who just stopped me out of curiosity and asked who I was. Occasionally they would take my blue eyes for being German and not American. Once at least when I said I was an American instead of a German, the face lengthened, but then he got curious more than taken aback and asked me questions about the United States.

QUALITY OF SOVIET INSTRUMENTS

Mr. BROOKS. What was the character of the instruments that you saw used in scientific endeavors? Were they up to the standards that you see in this country? Were they better or were they inferior?

Dr. BALDES. And where were they made?

Dr. NOYES. They were made in Russia. Without having used them myself, it is a little hard to answer your question about whether their quality is as good as ours, but in at least a few instances I saw machines, for example, on electron spin resonance, so-called, in this laboratory in Moscow which gave perfectly beautiful pictures of the resonance in organic molecules. Really they were better, I think, than any I happened to have seen in this country. So I would say on the general level you would have to assume their instruments are pretty good; that is the best I could say.

SOVIET ACADEMIC STANDARDS IN SCIENCE

Mr. BROOKS. From talking to your host and others there, were you able to form any estimate of the standards set by Russian science?

Dr. NOYES. Yes. To some extent, although, for the reasons I gave you at the beginning, one has to mistrust a little bit a person who has been there as short a time as I was. I asked in particular how they chose their professors for the university, because this concerns all of us. No university is better than its faculty, and if these men aren't carefully chosen then one has to assume that the university will not maintain its standards.

Advanced degrees

Well, if a professorship in chemistry comes open at the University of Moscow, the duty of finding the successor is assigned to the faculty in chemistry. So the first thing that is done is to advertise in the newspapers that this vacancy exists. Anybody who has the so-called Soviet doctor's degree can apply for the position; that is, doctor's degree in chemistry, of course. And this doctor's degree is a much higher degree than ours. They have a "kandidate" de-

gree which corresponds very roughly, I suppose, to our Ph. D. But the doctor's degree is given after 5 to 10 years more of work and after a man has published a good many papers on his own. These are sized up. He doesn't pass any examination or have to write a thesis. But he applies for this doctor's degree on the basis of his accomplishments.

Faculty appointments

So it is a sort of semihonorary degree, and there are about 6,000 of these in the Soviet Union in all fields. Anyway, one must have this degree to be a professor at the University of Moscow. The people who apply are examined; that is, their credentials and careers are examined by the chemistry faculty. The chemistry faculty consists of the full professors in chemistry, plus a few representatives of the young faculty members elected by these young faculty members. Thus people like the assistant professors are represented on the faculty officially. They go over these credentials and, of course, I suppose, they have politics just like our universities have politics, and friendships may mean that there are votes for some people and not for others. So I asked him: "Suppose this procedure led to what was believed to be a poor person to be a professor; is there any safeguard?" And he said, "Yes, the council of the university reviews this nomination." To his knowledge the council had never turned down a recommendation from the chemists as to the person they wanted, but it can. The rector may overthrow a recommendation.

Then I asked what happens if the recommendation is overthrown. Then it is referred to the chemists of the universities of the U.S.S.R. But essentially they allow chemists to pick chemists. They don't trust some university president or dean who thinks he knows all about 40 fields to do the job. In that sense I think we might well learn something from their procedures.

Mr. BROOKS. You like the Russian system, then, in that respect?

Dr. NOYES. In that one respect. Don't mistake me, I don't like it in all respects. [Laughter.]

Mr. BROOKS. Mr. Bass?

FACULTY SALARIES IN THE U.S.S.R.

Mr. BASS. How are members of the faculty compensated?

Dr. NOYES. This is an interesting question. The salaries for all professors are the same except that they do go up with seniority, they tell me. That is, a salary gradually increases as one gets older. But if one holds an administrative post such as a director of an institute or a deanship then one is paid more.

Professor Seminov, the Nobel Prize winner, is obviously living extremely comfortably. He has a car with a chauffeur, and he has this apartment over his laboratory, which is unpainted but nevertheless has a nice view, and one just gathers that he is comfortably situated.

Mr. BROOKS. As I remember, a chauffeur draws about $10,000 over there, too.

Dr. NOYES. I can't tell you what a chauffeur is paid; he may be paid more than some of our professors. I don't know.

Mr. BROOKS. Mr. Karth?

Mr. KARTH. Doctor, what is the equivalent pay of their doctors as compared to our scientific doctors over here?

Dr. NOYES. I think one might have to compare not the pay in dollars because there are three rates of exchange, as you are well aware. The official rate of 4 rubles to the dollar which nobody uses, the Intourist rate of 10 rubles to the dollar which is what we get as tourists and occasionally some of our group were stopped on the street and offered 25 rubles to the dollar on the black market. So you can take your pick as to what the ruble is worth. I think you have to compare rather the pay of a professor relative to that of a workman over there. On that basis I would gather the professor, the good professor, the eminent one, is getting about 10 times as much as the man who would be classified as a common laborer.

What does a common laborer get here, $3,000 or $4,000 a year maybe? There are very few professors getting $40,000 a year I can assure you of that.

Mr. BROOKS. Mr. Hechler?

TRENDS IN SOVIET EDUCATION

Mr. HECHLER. There has been a good deal written about the differences between Russian and American education and the emphasis in the last few years in Russia on education and you have given us some excellent specifics. What would your overall conclusions be about the future implications of the trend in emphasis of Soviet education, so far as the future security of this country is concerned, over the long haul? Have you formed any general overall conclusions on the basis of that?

Dr. NOYES. Well, the Russian system, in common with most of the systems in Western Europe—this is not peculiar necessarily to Russia—is a competitive system. The boy or girl who is going up through the educational system is compared with his fellows, or sisters, and it is only the good ones who survive and go on year by year into the higher levels and up to the university. It is quite different from our system, where with 200 different institutions giving bachelor's degrees, if you can't get into a good one you can go to a less good one, provided you have the money. This is not true in the Soviet Union. The students are handpicked. I can only answer your question partially, as follows: I spent last October in the United Arab Republic at the request of our Department of State. And they have had about a thousand students studying in the Soviet Union in the last 2 or 3 years. I talked to some of these chaps. In fact, I have one of them working with me at the University of Rochester, today. There is one thing these boys seem to be proud of: while they were in Russia they were held to high standards. This I think is something we could stop to worry just a wee bit about. Are our standards academically such as to be compared favorably with those over there? I am sure our best students are just as good if not better than theirs, but we have a lot of others, too.

Mr. HECHLER. Your conclusion, then, is, without adopting whole hog any aspects of the Russian system, we yet can gain some lessons from it?

Dr. NOYES. I wouldn't by any means adopt their system. Because some children develop slowly; I think the competitive system weeds them out too early.

Some of our chaps who in the twenties find themselves, catch fire and become fine people. They would have been weeded out in Western Europe as well as in Russia, in my opinion.

I wouldn't adopt their whole system, but I do think we should look at it and take perhaps some of the better lessons we can learn from it. That is all.

Mr. HECHLER. Certainly our investment in the whole educational system in this country could be emphasized more.

Dr. NOYES. I think that, plus the fact that with our 2,000-odd institutions we may be scattering our efforts too far. Can we find good faculties for 2,000 places? Isn't it better for the very good student to have a little competition by being with good students? This is the kind of thing we need to worry about, I think.

Dr. BALDES. In your observations what would be the ratio of boys and girls in the field of science?

Dr. NOYES. It varies from one field to another. The girls are very numerous in medicine, perhaps two-thirds of the people are girls. In physics, it is more like 2 to 1 in favor of the boys, and in engineering I am told it is even higher than that and the vast majority are boys.

Incidentally, without any insult to our friends in engineering, engineering is not deemed to be worthy to be a university subject in the U.S.S.R. [Laughter.] It is given in technical schools, but not in the University of Moscow.

REMARKS BY DR. MAURICE J. ZUCROW

Dr. ZUCROW. Well— [Laughter.] If you take a look at the definition of "university" it has nothing to do with level of intellectual accomplishment. A "university" is an assembly of people who are specialists and one can come and study with them without participating in a formal professional program.

An enginering-school education is a professional program and the inference in your remark—I am not saying that you inferred it—is wrong. It is my understanding that it is because engineering is so important to the U.S.S.R., engineering education has been transferred from the universities to special engineering schools.

Now, I wanted to ask you a question that I think is really important. I have some enrollment figures here; they indicate what has happened to engineering enrollment, in the freshman class in the United States, in the years 1957, 1958, 1959. I obtained the figures from a paper by F. C. Lindvall, Engineering Science magazine, California Institute of Technology, March 1960.

I intended to prepare a statement on this subject, but I had an eye infection so I was unable to do so. But since you are talking about education in Russia, I would like to get some comment from you on the enrollment trend.

In 1957, 17.8 percent of all male freshmen were engineering freshmen; in 1958 this decreased to 15 percent; in 1959 this dropped to 13.6 percent. There is a decrease in engineering enrollment both percentagewise and absolute.

According to this same paper the Russians expect to nearly double the 1958–59 rate of graduation of engineering graduates by 1962 while we will have almost a 40-percent increase.

Now, can you tell me, did you find whether the U.S.S.R. is increasing its educational efforts to increase the number of graduates in the basic sciences, such as chemistry, mathematics, and physics?

I have some figures here on the status of scientific manpower in the United States. According to the same paper, they are from the National Science Foundation. In addition to engineers, there are in this country—and these figures are very approximate, I have used round numbers—130,000 chemists, 50,000 biologists, approximately 25,000 earth scientists, and 20,000 physicists. In other words, we are rather low in physicists. We also have, roughly, about 7,000 mathematicians.

Now, approximately a half of all the basic science personnel is engaged in university work; the rest are scattered through industry.

We have about 600,000 engineers, and of them only approximately 2 percent are in academic institutions, and 14 percent of the engineers have more than 5 years of college education, and this percentage should increase in the future. It will increase, however, only if we can find the money for supporting those who should do graduate work in engineering.

Now, if we are going to expand our efforts in science and technology—and this is what I think is a problem which is a part of the business of this committee—we must be concerned with policies and methods, we must look into policies and methods which will enable us to do this. I feel strongly that we are in a technological race, not only in space but in every area of science. Therefore, we must plan, so that no important area of science and technology will be neglected.

So I would like you to give me your opinion if you can whether the U.S.S.R. is increasing its effort to graduate more chemists, physicists, biologists, earth scientists, and mathematicians to the same extent that it is doing in the field of engineering.

DISTRIBUTION OF EFFORT BY FIELDS IN THE U.S.S.R.

Dr. NOYES. The ratio of people in these various fields you have mentioned in the U.S.S.R. is very different from the United States.

You probably realize, as I do, that chemistry in the 1920's had a big expansion in the United States. The chemical industry has grown in the last 35 to 40 years since World War I, enormously. So while the figures you give of percentages of people in academic life apply to the whole of science, in the chemistry field, where you have 100,000 people, only 15 percent are in academic life and most of the other 85 percent are in industry.

Now, in Russia they have developed physics, for obvious reasons, nuclear physics, physics of all kinds, so you will find more physicists than chemists over there, if the figures I have are right, and I won't guarantee them.

But they have found that their chemical industry has lagged. So they are making a deliberate effort to train chemists.

To come back to your question, I am sure they are doing as much for the basic sciences as for the others, but there is one point they

have begun to realize, namely, that a research institute set off by itself apart from the university becomes sterile. They are now combining these research institutes which have been alone, with universities so that the young people will go to the institute sometimes for their research and so forth.

One advantage of a university is the turnover of young people, of the uninhibited young minds that are not afraid to express opinions. These students are trained for the Ph. D., and then go on. Hence there is always fresh blood coming into a university.

If one isn't careful in a research institute, the people may get old and sterile and become administrators instead of scientists.

Dr. BALDES. I have heard it said that every Ph. D. in Russia must go back into teaching for 2 or 3 years before going on into research.

Dr. NOYES. I can't answer the question.

Dr. BALDES. In other words, that assures a very excellent teaching program.

Dr. NOYES. This advanced doctor's degree I was talking about is practically similar to the degree in the United Kingdom. Their "kandidate" degree is much more widely given and is like our Ph. D. here. So I can't answer your question. I don't know.

Mr. BROOKS. You referred to only 6,000 of these advanced doctor's degrees, and they are taken up by the university or the colleges. What would you do then for advanced doctorates outside of the universities?

Dr. NOYES. Perhaps this particular kind of a doctor's degree that is the semihonorary type is not so necessary in industry, in plants, as it is in the universities. It is just a peculiar trademark which supposedly qualifies a man to become a professor. I don't think it has much more use than that.

New science city in Siberia

They are starting, you might be interested to know, a new city for science. It is roughly in the geographical center of Siberia. They are going to have about thirty to forty thousand inhabitants in this city, of whom five to six thousand will be scientists.

Mr. BROOKS. That is east of the Ural Mountains?

Dr. NOYES. East of the Ural Mountains.

This Professor Vojevodsky, who was kind enough to show me around the institute in Moscow, was going there. I asked him whether he was going voluntarily.

He said, "Sure; I have a wandering foot, I like to travel now and then. I am glad to move. I will keep a couple of people working for me in Moscow so I can come back occasionally each year."

Mr. BROOKS. What are they going to do, what sort of science are they going to teach in that new city?

Dr. NOYES. Practically everything. I don't know too much about it, except that it is a scientific city.

Mr. BROOKS. From the ground up?

Dr. NOYES. From the ground up. It is built for that purpose. I don't know whether they will get to fighting with each other or not. Scientists are individualists, you know; they don't accept orders from anybody.

Mr. BROOKS. Any further questions, either from the committee or from the panel?

(No response.)

Mr. BROOKS. Doctor, you can tell by the questions and comments here that we are all deeply interested in what you have to say with reference to Russia.

Now, we are going to try to finish up a little early so we can go into executive session. At that time we may ask you some executive questions.

Dr. NOYES. Please, sir, don't assume that I was converted to their form of politics. [Laughter.]

Mr. BROOKS. Next we have this morning our good friend who was here with us before, Prof. James A. Van Allen of the Department of Physics of the State University of Iowa.

Dr. Van Allen, I think it would be preferable if you would take the microphone. They can hear you better in the back of the room.

Mr. WOLF. Off the record.

(Discussion off the record.)

Mr. BROOKS. You have a prepared statement, I believe, and I think the members of the committee have been given copies of that statement. We would be happy to hear you.

PAPER BY DR. JAMES A. VAN ALLEN

Dr. VAN ALLEN. Mr. Chairman, gentlemen, the scientific area in which I am working personally is one now coming to be known as space science. For a variety of reasons, Federal support of space technology and of space science in the United States has increased at an explosive rate during the past 2 years.

Among other developments, a major new Federal agency, the National Aeronautics and Space Administration, has been created with an annual budget which will approach $1 billion in fiscal year 1961.

Therefore it cannot be said that space science is being starved for lack of Federal support or of public encouragement. Yet there is, in my opinion, at least one remarkable and very deep-seated omission.

Let me illustrate this omission as follows:

Universities the source of long-term competence

In the 9 years during which I have been teaching at the University of Iowa I have devoted a large part of my efforts to advanced students in the space sciences. During this period my associates and I have sent forth 10 Ph. D. students and 20 master's level students, of all of whom we have been quite proud, with special research training in space science.

Thus, we average about one Ph. D. per year in this field. I believe no other university has done as well.

Indeed, the total production of Ph. D.'s in fields which might be broadly entitled "space science" is probably less than a dozen a year in the whole of the United States, a truly shocking contrast to the national need.

With these considerations as a specific point of departure, I have adopted it as my special mission with this panel to attempt to represent what I believe to be a general and a central problem in the long-

term national competence in the basic sciences and in the technological and engineering fields which stem from them; namely, the support of graduate study and research in the universities of this country.

I do not believe that universities are in danger of dying out. Indeed, universities have demonstrated a durability over the centuries which is one of the marvels of human culture.

Yet the problem is rather whether universities are developing at the rate appropriate to the national need. I believe that they are not, especially in the area of the basic sciences, physics, astronomy, chemistry, biology, geology, and mathematics.

The contrast between the level of Federal assistance to universities and that of its direct support of industrial and internal governmental research and development agencies is a very striking one; indeed, it is almost ludicrous—in a grim sort of way.

Yet the universities have been and must continue to be the wellsprings of the expert talent which is the root of all the technological developments which are essential to our national competence in the defense area and to that of our civilian economy.

We used to be impressed during the war by the estimates that the Government expended some $100,000 on the training of a military pilot. In many of the modern fields of experimental physics, $100,000 would be a minimal estimate of the investment in every Ph. D. which we produce.

In the advanced work in a university our aims are two: First, to give the best possible training to capable and interested young men and women in a specialized field of learning and to develop a toughmindedness and resourcefulness in scholarly investigation.

Second, to develop new knowledge for its own sake.

Of these two aims, the first is perhaps more essential than the second, but the two are so intertwined that they cannot be, really, separated.

Now, I ask this question: What do universities most need in order that they may discharge their obligations to the Nation in this 1960 era?

University financial needs in science

And my answer is: Two things. First, physical facilities: and second, institutional grants of a broad character to enable discretionary development in the directions judged on a local basis to be the most fruitful.

Parenthetically, I may say that I believe that the funding of specific projects of specific interest to the various branches of the Federal Government can be said to be well provided for at the present day.

Also I feel that the Federal support and encouragement of technological applications of scientific knowledge is not in need of immediate attention.

For better or for worse, the immense military appetite for technological developments assures adequate emphasis; and the vast organization of the Department of Defense assures an adequate voice to Congress on such matters—to put the matter with what I consider polite restraint. [Laughter.]

1. *Physical facilities.*—Now, on the subject of physical facilities for universities: In the area of physical and mathematical sciences the National Science Foundation and the Atomic Energy Commission are

the only Federal agencies which have, to my knowledge, any proper view of the needs of universities for physical facilities; that is, research laboratory buildings and experimental equipment. And only the National Science Foundation has an enabling act endowing it with sufficiently broad responsibility and authority to meet the general national problem.

As an example of a major Federal agency which does not have such a view, I may cite the National Aeronautics and Space Administration. I find that the fiscal year 1961 authorization for NASA contemplates $122,787,000 for construction and equipment in Federal laboratories.

But I am unable to discover as much as $25 for a workbench at a university, from which the expert talent to staff these facilities must come.

The National Science Foundation is making a stalwart effort to bolster the research facilities at universities, but congressional reception of their requests has been, thus far, so cool that they have been forced to veil their efforts under the innocuous sounding term, "modernization program," and their annual appropriations in this area are at the level of several millions of dollars a year, whereas the clearly demonstrated needs total 10 to 20 times that amount.

I have found it illuminating to survey the record of the Federal Government in the matter of support of physical facilities for universities. The Public Works Administration during the period 1933–39 was notable for its activity in this field. The following information is from the official document entitled "America Builds—The Record of PWA" (U.S. Government Printing Office, 1939):

In all, PWA has made allotments to 662 college projects, with a total construction cost of $198,164,000. Out of 69 land-grant colleges, PWA helped build new facilities on all but 8 of them (p. 135).

From the summary table we find under the heading of "Educational Buildings for Colleges and Universities" the following (p. 288):

Number of projects	662
Estimated cost	$198, 164, 689
Funds supplied by applicant	87, 258, 807
Federal allotment	110, 905, 882

The Federal allotment is further divided as follows:

Loan	30, 458, 829
Grant	80, 447, 053

Most of these "projects" were for the construction or reconstruction of academic buildings, dormitories, student recreational facilities, etc. These buildings stand today, jammed with students, as one of the most durable evidences of enlightened Federal activity at the local level.

The assistance for construction of university buildings in the medical and biological areas is a most notable example of Federal activity at the present day. Under the Hill-Burton Act some $100 million is provided annually in matching funds for the construction of hospitals and medical and biological research facilities. About one-fourth of this amount goes to institutions conducting medical training.

During the 12-year period 1946–58 (see Hill-Burton Hospital and Medical Facilities Program 1946–58. U.S. Public Health Service Publication No. 616 of 1958) 3,725 building projects were completed or

approved out of a total estimated cost of $3,073,552,000—of which the Federal share was $957,528,000 (or 31 percent) and the State or private share was $2,116,024,000 (or 69 percent). And the program is being continued and expanded.

The matching fund recipe of the Hill-Burton Act—roughly $2 of local money to $1 of Federal money—is one of the finest of legislative history. First, it is a powerful stimulant to action at the local level. Second, it provides an automatic assurance of the soundness of requests.

I urge a similar program of similar scope in the area of the physical sciences. There is, I feel, no Federal contribution to higher education which is so neglected, so clearly needed, so durable, and so politically noncontroversial as buildings and laboratory facilities in the general pattern of the Hill-Burton Act.

2. *Institutional grants.*—At our first meeting I referred to a second need in the field of graduate level study in the sciences, namely, that for lump subsidies or grants to universities for general discretionary use at the local level.

I am delighted to learn that the National Science Foundation now has before the Congress for approval a specific plan of this nature. It is what might be called, in short, the 5-percent plan.

The plan is as follows: To every institution which has been receiving NSF grants for specific research undertakings, it is proposed to send an annual bonus equal to 5 percent of the aggregate amount of these grants. This lump institutional grant, as it is called, may be used in any one of the variety of ways in accordance with local needs—for example, for fellowships, purchase of equipment, travel to professional meetings, support of scholarly publications, and so forth.

This pilot program, though modest in scope, is revolutionary in concept. *And I urge that it receive the support of this committee.*

Thank you very much, Mr. Chairman.

Mr. BROOKS. Thank you, Dr. Van Allen, very much, for a challenging statement that you have given.

In your main statement, you urge similar action, that is, to the Hill-Burton law, for physical sciences.

Now what do you include in the term "physical sciences"?

Dr. VAN ALLEN. Physics, chemistry, biology, geology, and mathematics.

I am sure that Dr. Zucrow would like to include engineering sciences, and I should, too, in the more fundamental areas.

Dr. WHIPPLE. How about astronomy?

Dr. VAN ALLEN. Astronomy, yes. I must apologize for this horrible omission. Astronomy we consider to be applied physics. [Laughter.]

THE HILL-BURTON ACT FORMULA

Mr. BROOKS. That being the case, what you would do would be to have the universities, would you, make the initial allocation of funds on the basis of 2 to 1, and then the United States would match that?

Dr. VAN ALLEN. Yes, sir. I think that is essentially what I would propose.

I believe the Hill-Burton law has been in practice an eminently successful one over the some 14 years of its history. It has been ex-

tended year after year and in fact expanded during that period. I think it provides a demonstrated recipe for how the Federal Government can aid in a very vital way the educational functions in the United States.

Mr. BROOKS. I think it has been eminently successful, too.

Any questions?

Dr. VAN ALLEN. I feel it is the best model we have of how to go about such an enterprise, if it is indeed agreed that it is valuable and important to do so.

Mr. BROOKS. You would include, too, not only the building itself but the fixtures and equipment?

Dr. VAN ALLEN. Yes, sir.

Mr. BROOKS. Those things that are needed to make an operation complete.

Dr. VAN ALLEN. Yes, sir.

Mr. BROOKS. Dr. Hechler.

Mr. HECHLER. I think this is an outstanding statement, Dr. Van Allen. I certainly hope that the country and Congress will wake up to the importance of the universities in this whole field. I for one am not going to be so cool as you indicated here on page 3 of your statement.

Mr. BROOKS. Any further questions or comments?

Dr. Baldes?

PROBLEMS OF THE SMALL COLLEGES

Dr. BALDES. I happen to know that it is absolutely impossible for a smaller college, no matter how excellent it is in the training of its students, to get funds for a new science laboratory, including physics, chemistry, and what not. There are no funds whatsoever available in this country. You can get funds for a dormitory on a 5-percent interest basis or something, but there is no profit in the science laboratory. It is all expendable, both for the building and as far as the Government is concerned, I take it, and for the equipment therein.

Dr. VAN ALLEN. Yes, sir.

Dr. BALDES. There is nothing available for a small college that needs a new science laboratory for experiments.

Dr. VAN ALLEN. The American Institute of Physics has recently made a comprehensive survey of the need for buildings in the area of physics alone, in the United States. The estimate is that $250 million will be required over the next 5-year period to properly develop the teaching and research functions in physics, in terms of buildings and facilities alone.

I think that gives one some measure of the problem.

Mr. BROOKS. You would make that applicable only to the higher university and not to the high schools?

Dr. VAN ALLEN. Yes, sir. I am very impressed when I visit our local high schools to see how far better equipped and fitted out they are than the universities. I think the universities are really the poor cousins of American society.

Mr. BROOKS. I once advanced the idea that we should have in all universities a building dedicated to military science. Whether it would come within the terms of your definition of physical sciences, I don't know.

Mr. HECHLER. If the chairman will yield, doesn't the National Defense Education Act take care in some respects of equipment in the high school laboratories?

Dr. VAN ALLEN. It certainly helps a great deal; yes, sir.

Mr. HECHLER. The same thing certainly could be extended and applied in higher education at the university level.

Dr. VAN ALLEN. Yes, sir. But it is my impression, and I believe it to be a sound one, that the high schools are much closer to the people than the colleges and universities; and the hometown high school, I think, fares on the whole much better than the more detached institutions of higher learning.

Mr. HECHLER. I would like to underline the point made over here about the smaller college that doesn't have the Federal grant for research——

Dr. BALDES. For teaching.

Mr. HECHLER. For teaching, to begin with. I think they are the ones that are really starved.

Dr. VAN ALLEN. I believe it is correct that the present National Science Foundation plan contemplates, first of all, institutions giving doctoral work in the sciences.

I believe they also have surveyed the independent 4-year colleges, and hope to work on them during the next few years.

Mr. QUIGLEY. Doctor, I am not cool but I think I am a little skeptical about applying the Hill-Burton formula to the laboratory facilities of a college or a university.

What would it cost to put up a good physics laboratory? Are we talking about $2 million, $5 million?

Dr. VAN ALLEN. It certainly depends on the size of the institution. I think it is like that, $1 million or $2 million.

EASIER TO FINANCE DORMITORIES THAN LABORATORIES

Mr. QUIGLEY. All right.

Let's take a $3 million hospital under the Hill-Burton Act; $1 million of that $3 million will come from the Federal Government. If a local community will go out and raise half a million dollars, if they have got a million and a half, and they can pick up the mortgage, get a mortgage for the rest, because they have a hospital, they are going to have patients, there are going to be fees paid on a daily basis and the mortgage can be paid off over 20 or 30 or 40 years.

We can build dormitories on our college campuses because a campus can raise $250,000, and then get a $750,000 long-term Government loan, and from the tuition and the board, that loan can be paid off.

Suppose we had such an act as yours and we said: All right, under the scientific Hill-Burton fund we will give you a million dollars. Query: Where would you raise the other $2 million?

Dr. VAN ALLEN. It is certainly a problem. I agree with that, of course. [Laughter.]

I think the attractive things about the matching funds scheme are, first of all, that it is a very stimulating thing at the local level, and I think that is a very fine thing.

Secondly, it gives the Federal Government a powerful assurance that it is a sound and proper, well-considered request when matching money is obtained from local sources.

Now it may be that it is impractical in this area; that I don't know.

Mr. QUIGLEY. You see what I am thinking is that you can't—at least I assume you can't—go to the average bank or the average insurance company and pick up a million or a million and a half mortgage on this kind of thing because you don't have the income that you would have in a hospital, you don't have the income you would have from a dormitory.

Dr. VAN ALLEN. Yes, I think academic buildings are the most difficult thing, far and away.

Mr. QUIGLEY. While the Federal Government might make available a million in a grant, it wouldn't be as it is under Hill-Burton that all you would have to raise would be half a million in cold cash. You would have to go out and get $2 million, and this could be mighty difficult to do.

LOCAL FUNDRAISING

Dr. VAN ALLEN. Yes. I think the recipe is certainly a thing that needs to be studied very closely.

It seems to me the alternative to matching funds is a critical independent study by perhaps the National Science Foundation of the local problem and the local need and the local competence, and that would be perhaps an alternative to matching funds. It would give the Federal Government the proper assurances that it is a sound request.

Mr. QUIGLEY. I have a feeling that the small college that the doctor is referring to would actually be no better off and would be even more miserable in its misery, because they would realize that these Federal funds are available if they could only manage to get the local funds to start the thing. And I think you are still going to have trouble with the small college raising even the starting money.

Dr. BALDES. The college I have in mind, I would rather not mention it, they are raising about $2 million from business and friends of the college alumni and so on, to put over this science building.

Mr. QUIGLEY. These would be contributions?

Dr. BALDES. All in contributions. There are no other funds they can get whatsoever to help.

Mr. QUIGLEY. In a case like that, a million-dollar grant from the Federal Government would mean the difference between an adequate and an outstanding facility.

Dr. BALDES. Absolutely right.

Mr. BROOKS. Mr. Roush?

Mr. ROUSH. Mr. Chairman, I would take issue with Mr. Quigley on this. I happen to be a trustee of a small college and we have been engaged in fundraising for many projects. At the present time, we are in the process of raising funds for a laboratory, a science building.

And I think not only would this help but it would provide the necessary stimulus to bring about the giving and contributing we are trying to get people to accomplish, at least in our instance, and I think it would be so in other instances.

People will give, but sometimes you have to prod them a little bit. There has to be a stimulus, there has to be a goal or something to strive for. If they know these funds are coming, if they can match them, or even, say, give a third of it, I think we would have no difficulty in raising funds to match a Federal grant.

Not only would we be able to provide adequate or, say, superadequate facilities where before they were only adequate, but we would be able to provide facilities where we would have no facilities if it were not for this particular program.

Mr. BROOKS. You would not exclude parochial schools, either, would you?

Dr. VAN ALLEN. No, sir.

Mr. BROOKS. Dr. Whipple?

FUNDS DERIVED FROM RESEARCH

Dr. WHIPPLE. There is another source of funds practically for a research laboratory which might help quite a bit in this problem; namely, the income from rental charges either out of overhead or direct costs in Government contracts, when contracts are a considerable portion of the activity of a research laboratory.

Thus a university could soundly plan to put in a moderate percent of the cost of a building in the form of an endowment investment, which then they could hope to get a return on by renting in that fashion.

Mr. BROOKS. Mr. Wolf.

Mr. WOLF. A thought occurs to me, the question: Would there be an additional inducement to the small colleges if they were assured of Government grants to do certain projects if they could produce a set of equipment to do this project in as an inducement and encouragement to the college in case we do come with some Hill-Burton type proposal?

I would be interested in any comments you might have on this. We talked about the question of grants to the small colleges, the specialized colleges and schools.

Dr. VAN ALLEN. Sir, if I may, I think it is a very great mistake to think of 4-year colleges as research institutions. They really are not. Their job is teaching at the bachelor's level.

I think any support which might be developed for 4-year colleges should be thought of as an aid to instruction and development of young people and not as a research enterprise.

I am quite familiar with a number of small colleges in Iowa, and have a good deal to do with them. Some of them have the feeling, and you might even call it mild pretense, that they are doing research. But I do not think it should be classed as that.

Mr. WOLF. How do these colleges now get the equipment? What are the various methods by which they get equipment?

I admit it is woefully inadequate, but——

Dr. VAN ALLEN. Of course, they have income from tuition. The rest they really beg.

I am on the science board of visitors on my alma mater, and I am one of the assistant beggars for equipment there, and I know it is a long, hard fight, and the outcome is usually very inadequate.

Mr. WOLF. Would you envisage any possibility that there might be grants for specific pieces of equipment given by the Government?

Dr. VAN ALLEN. I think there might well be. I think it should be treated frankly as teaching equipment and not under the guise of research equipment.

Mr. MOELLER. Mr. Chairman.

Mr. BROOKS. Mr. Moeller.

A SCIENCE ACADEMY TO MATCH MILITARY ACADEMIES

Mr. MOELLER. I wonder if we could hear the doctor express—I gather from the paper what he might say—but whether he would express himself with respect to the Federal Government establishing an academy comparable to West Point, Annapolis, et cetera, for the basic sciences, with the Federal Government paying the bill and letting the cream of the crop go there for further research and further study.

Dr. VAN ALLEN. I would say very candidly, I am quite stiffly opposed to that. I think we have some excellent universities in the United States. We have a wealth of tradition of scholarship, and the point of view already developed in universities which are the proper foundation on which to build, I feel.

There are a few Federal institutions of higher learning, such as the advanced technological institutes of the Armed Forces and, although they doubtless have a useful function, they are not universities; they are too narrow in scope to serve a broad national function.

And I fear that this would be the case of a Federal university established as a specific technological institution.

Mr. MOELLER. It would be comparable to the Moscow Academy of Science?

Dr. VAN ALLEN. Moscow University is, of course, a federal institution, federal Russian institution, but it is much broader, I believe, than your question indicated you were thinking of. I may be wrong.

Mr. BROOKS. Mr. Hechler.

IMPORTANCE OF EDUCATION

Mr. HECHLER. Don't you think we will have to reorient our entire thinking toward the importance of teaching? Now it is very easy to get money for hardware, and we have educated people sufficiently so we can get more money for research if it is related to hardware or even basic research.

But we have got to go one step back of that and get the investment in teaching and recognize its value to the national security.

Isn't that true?

Dr. VAN ALLEN. Yes, sir. I may say I have almost daily contact with people in the aircraft industry, missile industry, and various governmental laboratories in this field. The woeful lack, in my opinion, is advanced training. It is not in technological capability, the lower level sort, but it is really in scientific sagacity, and I don't know where people possessing such sagacity will come from if they don't come from universities.

Mr. HECHLER. And we have to recognize the national stake in that.

Dr. VAN ALLEN. Yes. I think a good Ph. D. can save a million dollars a year for the Federal Government.

Mr. BROOKS. Let me interrupt at this point.

Dr. Furnas has just arrived. He was not able to be here before this time. My thought is, in getting over the work of the committee,

we could hear him and then go into executive session after that and hear everybody in executive session.

Some of us have questions we want to ask and some have ideas we would like to present to the committee. But I think in fairness to Dr. Furnas we ought to be in open session.

Doctor, we are happy to have you here, sir. Sorry you were detained, but we understand it.

I don't want to catch you when you are completely out of breath here from rushing into the committee room, but we are at a point where we would be very happy to hear from you as to your statement.

Now we have a microphone there. I suggest if you will that you take the microphone.

Mr. Finch will pass around copies of your statement.

Dr. FURNAS. Thank you, Mr. Brooks.

Mr. QUIGLEY. Mr. Chairman, while he is going to the microphone, I would like to make an observation.

I don't want to disagree with Dr. Van Allen, but I think our colleague on the committee, Dr. Hechler, is a very good Ph. D., and still I am not convinced that he is saving the Government a million dollars a year. [Laughter.]

Dr. VAN ALLEN. He is in the wrong field. [Laughter.]

Mr. QUIGLEY. His voters may think he is, but I am just not convinced.

Mr. BROOKS. Dr. Van Allen, we do appreciate your statement. You always present a strong, forceful statement with a lot of thought to it. Although it was short, it was to the point; it directs our attention to a basic need and we are happy to have you and appreciate your statement.

Now, Dr. C. C. Furnas is chancellor of the University of Buffalo.

Dr. Furnas, we have been in session two mornings; this is the second morning. We have heard from members of the panel following which we asked them a few questions in reference to their statement. And they can volunteer any additional information other than the statement. Then after that we expect to go into executive session. We are happy to have you and we will be glad to have your statement, Dr. Furnas.

Dr. FURNAS. Thank you, Mr. Brooks. I will read the formal statement here. I think I will just about have time.

Mr. BROOKS. All right, sir.

PAPER BY DR. CLIFFORD C. FURNAS

Dr. FURNAS. It is an honor and a great opportunity to appear before this panel and committee to present some thoughts on the problems and progress of science and technology. To many it must seem that the body of scientific research and its application to technology is appalling in extent and stupefying in complexity. I think all of us must admit that there are times when this seems to be the situation. This makes it ever more important to have discussions with bodies such as this in order to arrive, if possible, at understanding and perhaps even afford some appropriate guidance.

Though I have for many years and am still quite substantially involved in military research and development, I shall not dwell on

those problems and activities. They are very much before the public eye and there is a spate of discussion and debate in this area at all times. Perhaps this is an understatement. Neither shall I, glamorous though it may be, give consideration to space research or to interplanetary travel. As compared with those dramatic subjects, what I have to say will probably seem rather dull and perhaps uninteresting.

World population growth

One of the stark facts of life at the present time is that the world population is growing at an explosive rate. Tomorrow morning there will be more than 100,000 more mouths to be fed and bodies to be clothed and housed than there were this morning. Total world population at the present time is approaching 3 billion. One might say that these persons are divided into three camps. About 1 billion are in the more-or-less democratic world, about 1 billion under Communist influence, and about 1 billion are the so-called uncommitted peoples. Everyone recognizes the importance of convincing the uncommitted billion people that the democratic way of life as exemplified by Western civilization is the better course. So far, America's attempts to bring about such conviction have not been covered with glory.

At least one-half of the persons of the world exist in the most miserable imaginable circumstances. This is due to the lack of the rudimentary goods and services necessary to provide a decent standard of living. It is extremely important that science and technology provide the means for remedying this sad situation. It is not merely a matter of humanitarianism; it is a matter of political stability for the democratic way of life. America should be in a position to contribute most significantly, particularly by supplying new research knowledge.

If the situation as far as human existence for at least half the world is already sad and miserable, the prospects are that it may become much worse. Because of the rate of population increase, it is inevitable that by the end of this century there will be approximately 5 billion people on the Earth. Valid predictions are that by the year 2050 the number will be 10 billion. Eventually, of course, there will be a leveling off in this population density but the beginning of that trend is not yet in sight and probably will not occur for another generation or two.

It is evident, then, that if we are short of material goods and services at the present time, the world as a whole will be in a truly desperate situation when the population is doubled, unless something new is brought into the picture. I wish to discuss the type of research and development which will be necessary to take care of this critical problem.

Providing the requisite goods and services will depend not only upon scientific and technological knowledge, but also upon the supply of natural resources. Outside of agricultural land, our principal natural resources are: energy, minerals, and water. I will discuss each of them in turn.

Energy requirements

Industrial productivity in terms of goods and services is almost directly proportional to the amount of energy which is readily available. It is utterly impossible to provide the wherewithal for the lives of many billions of people by the old pattern of subsistence agricul-

ture alone. We must depend upon industry, which means that we must have ever-increasing amounts of energy available.

1. *Fossil fuels.*—As is well known, our principal energy supply at the present time is in the form of the fossil fuels: coal, oil, and gas. Despite the fact that new oil and gas fields are being discovered in various parts of the world, we are depleting this tremendous natural resource with extreme rapidity. As far as petroleum is concerned, in America we are already over the peak. The wells have to be drilled deeper and deeper and the output per day becomes less and less.

Hence, our increasing reliance upon foreign sources with occasional international political complications. No one can predict with exactness when the shortage of petroleum supplies throughout the world will become serious but everyone recognizes that the supply is finite and the day of serious depletion probably lies within the foreseeable future.

2. *Nuclear energy.*—The history of civilization will probably show that it was fortunate that the atomic bomb was devised and used at about the middle of the 20th century. Although military use came first, it did open up the door for the peaceful application of nuclear energy; that is, supplying controllable energy through the fission of uranium or thorium atoms. Uranium nuclear powerplants, as you know, are under development and a few are in use in this country, as well as in Western Europe and in Russia. I anticipate that in certain parts of this country the use of nuclear power will become economically feasible in competition with coal and petroleum within the next 5 to 10 years.

This will have a very important and beneficial impact for the supply of energy in certain forms (electrical energy and sensible heat at the source) in all parts of the world for a long time to come, but it is only a partial remedy.

If the intriguing and significant research on the controlled fusion (hydrogen bomb) reaction which is going on in many laboratories in this country as well as abroad, is successful, a great new source of energy will be opened up. It is too early to make predictions but this may come about within the next generation.

3. *Photosynthesis.*—It is not yet time to become complacent about the matter of energy supply. With our present devices and economies, we will apparently always need liquid fuels. We are also faced with the fact that conventional agricultural methods probably will not be able to supply all the necessary food energy for the population of the world in years to come. This means that we need to find out more about that great natural process known as photosynthesis, whereby plants take the energy of the Sun and a few simple chemical compounds and build up the substance of plant materials, which is the basis for all plant and animal life on the face of the Earth. It can also serve as the source of liquid fuels such as the gasoline which we use in our cars. Despite the extreme importance of this knowledge, we do not yet know how nature carries out the photosynthetic process.

In other words, we do not yet know the answer to that important, much-booted-about question, "What makes the grass green?" which you have heard of before. When we do find out this secret of nature, we will, in all probability, be able to improve upon the processes and carry out, on a feasible and economical scale, artificial photosynthesis

which will assure us of an adequate supply of liquid fuels, as well as certain basic synthetic foodstuffs, for all time to come. The energy which falls on the Earth from sunlight is thousands of times greater than the human race utilizes and the Sun will certainly be shining as long as there is a human race. Important fundamental research is going on in various laboratories upon the minute molecular reactions which form the process of photosynthesis but, in the national scheme, this type of research is still of minor importance. I feel that it should be greatly enlarged and emphasized.

Mineral requirements

The next natural resource which is essential to human industrial existence is made up of those materials classed as minerals. In this country and many others we have already skimmed the cream off our supply of metals and other natural minerals but the demand for them is growing even faster than the population.

1. *Natural ores.*—This is also true of the other industrial countries of the world. After we have depleted the mineral deposits which are economically workable with our present technology, where will we find these raw materials for civilization? We must learn to get more and more from less and less. Undoubtedly we can make small-step improvements in our technology for winning the minerals from the natural ores, but we need to make a major advance. There will be no single solution, so we need to explore all possibilities.

2. *Supplies in the ocean.*—There is one source of mineral substances which is practically infinite in extent even though the desirable materials are there in only very small proportions. I speak of the oceans of the world. If we could devise practical means for mining the oceans for the some 20 valuable minerals those waters contain, it would be of direct benefit to almost every nation. The answer, usually when you pose this question, is that such an approach is impossible because the minerals are there in such dilute concentration. However, there are certain low forms of life that do not know this and they go ahead and concentrate and use these minerals for their own benefit. I summarize this problem by posing the question, "How does the oyster get its copper?" Although the oyster is obviously a very stupid fellow, he is smarter than we are in the sense that he can take copper from the very dilute concentrations in sea water where it is present to less than one part per million and concentrate it by a thousandfold in its own body fluid. The slimy sea cucumber concentrates the element vanadium by a millionfold in its respiratory tract. Almost every form of plant and animal life has the ability to select and concentrate particular chemical elements, as a part of the living process.

How do they do it? Our knowledge is very fragmentary but it is obvious that highly selective chemical reactions are involved—which I call pickpocket chemistry—and about which we should know a great deal more. If we understood the real fundamentals of these selective reactions, we could undoubtedly improve on nature and would probably be able to carry out the processes, using nonbiological materials, on a large and economical scale. One can visualize such an industrial process where the input material would be sea water and the output would be several concentrated and well-separated minerals such as copper, zinc, phosphorus, boron, vanadium, columbium, and even

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gold. This would by no means solve all the mineral problems, but it could help substantially.

Parenthetically, it should be pointed out that two elements, bromine and magnesium, are presently being recovered from sea water on an economical basis. These two, however, are present in relatively large concentrations and are being recovered by conventional and well-known chemical processes. They represent about the limit of practical application of present knowledge.

3. *Low-grade ores.*—Even though the sea might become important as a source of minerals if we understood nature's tricks of selective chemistry, the knowledge gained might be even more important in developing new methods of winning the minerals from very low-grade ores. Simple leaching processes might be devised which would be economical and feasible. One example will indicate the possibilities.

Average granite, which makes up a large proportion of the Earth's surface, contains small traces of uranium and thorium, about 4 parts per million and 12 parts per million, respectively. If this uranium and this thorium could be effectively extracted and used in a nuclear power reactor, then that uranium and that thorium from a single ton of granite could produce energy equivalent to burning 50 tons of coal. The crust of the Earth will always serve civilization well when we learn how to use it.

I treated the problems and possibilities of this new type of chemistry in more detail in an address entitled "One Molecule in a Million" before the American Iron and Steel Institute 2 years ago. I am submitting a reprint of this address for the record.

Mr. BROOKS. The record will be happy to have it, sir.

Dr. FURNAS. Thank you.

(The document referred to is as follows:)

ONE MOLECULE IN A MILLION

(By C. C. Furnas, chancellor, University of Buffalo, Buffalo, N.Y.)

(The twelfth annual address in the Charles M. Schwab Memorial Lectureship, delivered in New York, May 21, 1958, at the 66th General Meeting of American Iron and Steel Institute)

It is indeed a great honor, as well as a truly great privilege, to be invited to give the Charles M. Schwab Memorial Lecture for 1958. I feel this particularly, because Mr. Schwab was a great pioneer. America has been built by the pioneering spirit which has been displayed in conquering the land, in industry, and in the quest for new knowledge. Mr. Schwab exemplified the strong, as well as the glamorous, aspects of the industrial pioneer and, hence, it seems appropriate to point this lecture toward new horizons. It has become trite to say that our frontiers are gone—but that is true only in the most limited sense. There is still a tremendous amount of pioneering to be done in our social and economic structure, and also in research in various aspects of our physical world. I plan to discuss today a frontier in chemical research which I feel has not been adequately explored, but which can open up great new territory, not only for knowledge but also for human welfare.

The title of this address is "One Molecule in a Million." Not only is a molecule an extremely small entity, one part per million is a very small proportion. Hence, I might be accused of devoting an undue amount of attention to minutiae of minutiae. But the ultramicroscopic segments of the chemical world still shelter many valuable secrets of intriguing scope and great potential significance.

For the most part, the physical substances which we see or feel, or sense in some other way, are made up of molecules which, in turn, are made up of different kinds of atoms. Many of these atoms carry well-known names, such

as hydrogen, oxygen, carbon, iron, etc. Water, the most common of substances, bears the familiar formula H_2O, which merely means that each water molecule contains two atoms of hydrogen and one of oxygen, neatly tied together by certain chemical forces.

A great deal is known, of course, about the chemical composition and physical character of hundreds of thousands of substances, from materials as simple as water to the very complex body-proteins, in their stable, or static, condition. Also a great deal of knowledge is available about the gross, or overall, results when chemical reactions take place between vast numbers of molecules. But surprisingly little is exactly known about what actually takes place in the minute, fine structure of individual molecules. Methods have not been developed to separate the individual molecules from each other and observe how they act as entities. We only see through a cloud—indirectly and somewhat darkly.

The chemist who wishes to know how individual molecules behave in chemical reactions can have sympathy with the astronomer who endeavors to acquire knowledge about the solid surface of the planet Venus. Venus is perpetually shrouded with a thick cloud layer. No human eye has ever seen its surface nor has any photographic plate ever recorded it. Astronomers, by various observations, have learned a great deal about Venus—its size, weight, density, temperature and the composition of the cloud layer—but no one has any direct knowledge of what actually goes on, on the body of the planet itself. Analogously, the chemist cannot determine what goes on in, or at, individual molecules, because he always has to deal with so many of them that individual actions are lost in the mob.

Why has it not been possible to observe individual molecules in action? Essentially because they are extremely small. For instance, a very minute and invisible particle of fog, one micron (a millionth of a meter) in diameter contains about 10 billion water molecules. That number is several times as great as the entire human population on the earth. But chemists, despite the refinements of their science at the present time, are not able to study the reactions in a sample as small as that. Even with the most modern methods, they deal with samples that usually contain at least 10^{14} to 10^{15} molecules. Hence, any chemical reactions they study are the gross effect of the interaction of a tremendous number of molecular entities.

It is my thesis that a great new field of useful knowledge will be opened up, particularly for the wise use of our natural resources, when we develop methods for determining the chemical kinetics of individual, or a very few, molecules. Such a statement would be quite without foundation were it not for the fact that living organisms do have the ability to literally pick one molecule out of a million and carry on useful chemical reactions which we do not yet understand.

Take oysters. Though they are now out of season we can at least give them consideration. Sea water, which is the traditional abode of oysters, contains about one part per million (by weight) of the well-known metallic element, copper. No one would question that the oyster is a very stupid fellow. But by some process, of which we are to date entirely ignorant, the oyster, like a pickpocket in a mob, is able to pick those rare copper-bearing molecules out of his watery environment and concentrate them inside his own body by about a thousandfold.

But the oyster is not a particularly outstanding performer in this concentration business. Many of his compatriots in the society of sea organisms do a great deal better. The lobster has a concentration of iodine in its interior structure which is several thousand times that of the surrounding sea water. The slimy and repulsive sea cucumber builds up a concentration of 10 percent of vanadium in its respiratory tract.[1] This is a concentration increase of something like a millionfold. Recently a paper from the Marine Biological Association Laboratory of Plymouth, England, in the British scientific journal, "Nature," stated that researchers have found appreciable quantities of the important metal, niobium (often called columbium) in the flesh and blood of ascidians,[2] the family of sea animals represented by the familiar skate. Niobium has recently achieved great importance in the hardening of high quality steels and in making aircraft steels corrosion resistant and more useful at very high temperatures.

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[1] This and following footnotes are referenced at the end of this article.

The ability of living organisms to build up concentrations of various elements is by no means limited to the ones I have mentioned. It seems almost to be a universal characteristic. We do not need to go to the sea for examples. Each of you has one close at hand, namely, his own body. By what process does your own biological equipment take the minute traces of iodine in your food and build them up by some one-hundred-thousandfold in your own thyroid glands? Or, how about the iron in your blood, or the calcium in your bones and teeth? These are all biochemical reactions which literally pick one molecule out of the multitude and build it into a new, more concentrated chemical structure for biological purposes. Despite all the research that has been carried on in biochemistry, we have to date but very little understanding of the true kinetics of reaction of the individual molecules which are involved.

In order to get some vision of the possibilities of these processes of recovering minerals from very dilute sources, we may well take the time for a quick survey of the history of mineral formation in the crust of the earth.

Living organisms are seldom given the proper amount of credit for their part in forming the character of the earth's surface. We ordinarily think that the undistinguished blobs of living matter which we see everywhere run through a certain life cycle, produce progeny, die and leave the surroundings very much the same as they were before. That picture, most decidedly, is not complete. An individual coral polyp does not change the character of the earth very much, but polyps in astronomical numbers build reefs and islands of quite pure limestone. To the casual observer, it would seem that the polyp has built these masses of land out of nothing. But, of course, they cannot do that any more than man can. The polyp takes the calcium compounds from very dilute solution in sea water[3] (about 4 hundredths of one per cent by weight or 400 parts per million) and builds up a shell of calcium compounds to protect itself. In this process of following its preordained metabolic ritual, it has concentrated calcium by several thousandfold, in the form of a mineral. Insignificant though the coral polyp may appear, it has been one of the most important creatures in changing the character of the earth's surface. The untold billions of tons of limestone in its various forms which are now a major constituent of the crust of the earth, and which is very useful in many ways, was formed by the coral polyps or similar organisms.

The simple creatures which made the coral islands are only a few of the multitude of species that exist on the earth. Practically every member of all the plant and animal families is imbued with the single purpose of living as long as possible and producing as many progeny as possible. But, inevitably tied up with all of these processes of juggling organic compounds through a life cycle, are certain phenomena of mineral metabolism. Few organisms exist without some metal compounds in their structure and, in nearly all cases, the concentration of the essential metal in the body structure is usually considerably higher than that in the immediate environment. Some times many, many fold higher. Thus the biochemical reactions offer many possibilities for the concentration of metallic minerals.

If, despite the evidence of the coral polyp, you think the feeble efforts of plants and animals have been insignificant in shaping the character of the mineral deposits of the earth, you should recall that life, in some form or another, has been scattered over the crust for probably a billion years; that it has been concentrating metals all during that period. You may further visualize the magnitude of the work if you realize that there are probably 10^{13} tons of living matter,[4] both plant and animal, on the surface of the earth today. If that same amount of living matter had existed on the earth for only half a billion years, and if the average life cycle were one year, then the total amount of living matter which has been engaged in this concentrating process over that period of time would amount to 5×10^{21}. This figure is approximately equal to the entire weight of the earth and 170 times the weight of what is considered to be the earth's crust.[5] Since the organisms have worked close to the surface, their total effort in concentrating minerals has been enormous.

From the data on the quantity of matter going through the life cycle each year, and its ability to concentrate mineral elements, it is evident that plants and animals may very well have been major contributing factors in building up billions of tons of mineral deposits—usually from very dilute sources. Many of the deposits of phosphates, of silica in the form of diatomaceous earth, of copper, iron, zinc, sulphur, arsenic, iodine and vanadium have undoubtedly been accumulated by living organisms. There are many other cases in which

living matter has probably been a most important factor. Some of the greatest iron deposits in the world are generally considered to be of biological origin. An important factor in laying down of the Clinton hematite (the iron ores of Birmingham, Alabama, Chattanooga, and central New York) seems to have been the presence of certain iron bacteria. In the process of formation of this ore, the leaching water contained iron in suspension or solution. The bacteria gargled the iron water and greatly concentrated that element in their insoluble body structures. It was essential to their life process. The water passed on but the skeletons of the organisms, with their high iron content, stayed behind, thus building up the high grade iron ores on which a great deal of industrial civilization is based.

Be it emphasized that while knowledge of the biochemical kinetics involved could help us in the future in winning and rewinning of the natural resources, I am not suggesting that we resort to cultivating and harnessing bacteria, microbes, oysters and sea cucumbers to do our mineral recovery for us. Biological organisms are too inefficient, too limited in their function, too temperamental, too restricted in their environmental conditions and too slow for keeping up with modern industrial needs. I do contend, however, that if we truly understood the minute details of the chemical mechanisms which these various organisms use, there is a very good chance that we could adapt this knowledge to new, carefully controlled, efficient processes, not associated with living matter, which could be of extreme industrial and human significance.

As industrial civilization advances, not only for the people of this country but also for the literally billions throughout the rest of the world, we are going to have to take stringent steps to keep the necessary supplies of industrial raw materials at hand. We are going to have to learn to get more and more from less and less and win and re-win all of our mineral resources from what now are considered to be completely inadequate sources of supply. The lowly organisms undoubtedly can teach us a lot, if we will but learn.

As one looks over the general field of application of geo- and biochemistry, he must admit that the very large potential in the mineral concentrating mechanisms exemplified in living matter, has not yet been harnessed. However, men have made various devious attempts in other directions at recovering valuable materials from dilute sources. A brief survey of some of the efforts to date would seem to be pertinent to this discussion.

In the 1920's the demand for the rather noxious and corrosive element, bromine, increased very sharply because it was useful in the process of making ethyl fluid for antiknock gasolines. Up to that time the source of bromine had been brines from wells in both this country and Germany, but these sources were proving to be inadequate. After a great deal of experimentation, a successful production plant for recovering bromine from sea water went on stream about 25 years ago at Wilmington, North Carolina, operated by the Dow Chemical Company. Pure bromine was recovered at the rate of about 50 thousand pounds per day from sea water. The concentration of that element in the sea water from which it comes is between 40 and 60 parts per million. This, however, is not a biochemical process. The bromine is merely replaced from its compounds by the use of a similar element, chlorine. This is a profitable operation because bromine commands a considerably higher market price than does chlorine. It is a straight chemical process, well controlled and effective, but it does not have the concentrating potential that many of the living organisms display.

During World War II, the sea also became a major source of supply for the well-known metallic element, magnesium. Magnesium is present in sea water to the extent of about 1 part per thousand.[6] Here again, however, the process is essentially a chemical replacement operation—calcium from limestone or oyster shells being used as the replacing element to release magnesium compounds which are later reduced to metal.

Chemical methods such as these for recovery of values from dilute sources certainly have their place and probably can be developed and exploited further than at the present time. However, they have their very serious limitations. By their very nature, they cannot be used for practical recovery from truly dilute sources, measured in terms of one or only a few parts per million. We still have something to learn from the living organisms.

Another process in which living matter *is* used for one of the steps in recovering copper from leaching waters has been reported recently by the Kennecott Copper Corporation.[7] It seems it has been the practice in recovering copper from mine dumps to use natural waste water that contains sulphuric acid and

ferric sulphate. The copper it picks up is removed by various methods such as precipitation on scrap iron. In the operation, the ferric sulphate is reduced to ferrous sulphate and is not useful for returning to the leaching process. Some strains of bacteria, however, have been discovered which, if kept in adequate numbers in a regeneration tank and properly agitated with air, reoxidize the ferrous sulphate to ferric sulphate, which is useful for still further leaching operations. This is an indirect boost from the bugs and I presume that the process may turn out to have a certain amount of significance. As far as I know, it has not as yet been reduced to large-scale practice.

I have dabbled a bit, myself, in the investigation of the possibilities of recovery of valuable materials from dilute solutions. About two decades ago, when I was actively engaged in university teaching and research and my life was not cluttered with a number of other things, I had some graduate students investigate the possibility of the use of base-exchange reactions as a means of concentrating metals from dilute solutions. The base-exchange reaction investigated is one with which I am sure you are all familiar, as it is the basis for the water softener operation, where sodium ions are exchanged for calcium ions, turning the water from "hard" to "soft."

Dilute solutions of copper sulphate were passed through a bed of zeolite, which is the heart of the base exchange process. The zeolite used was a carbonaceous type known as Zeokarb-H. In passing through this zeolite bed, the copper ions would be adsorbed, or would enter into a loose chemical combination with the compounds of the solid zeolite, and be retained on the surface. The bed would then be regenerated with sulphuric acid. Very substantial increases in concentration were obtained in this manner. Starting with dilute solutions (0.005 normal copper sulphate), increases in concentration of some 220 fold in one stage were obtained.[8] This sounds like a good start. If such a process were applied to a concentration operation, under idealized conditions, one pound of sulphuric acid which would be used for the regeneration would bring about an increase in concentration equivalent to the evaporation of 4200 pounds of water. It would seem that there should be some practical possibilities here.

It had been my intention to pursue this research further with the idea that a successful process might be developed for the recovery of both copper and zinc from brass mill pickle liquors but, with the advent of World War II, many things happened which prevented my ever returning to this research field and, as far as I know, the process has never been further developed, or used for the recovery of such metals.

It should be pointed out that, during the past two decades, there have been some quite marked advances in the synthesis of these base-exchange zeolites and they are used for many specialized purposes. For instance, a large part of the distilled water used in laboratories is now produced by the use of two different zeolites which remove first the positive and then the negative mineral ions which are found in tap water. Zeolites are also used for recovery of certain specialized metallic elements in some processes, but not on large scale. They are also used in research for the separation of some isotopes and for the recovery of some valuable organic materials such as some of the components of the vitamin B complex. Hence, there are quite a number of specialized uses but, as far as I know, the base-exchange process is not being used for the large scale concentration of the more common metals.

One of the more interesting efforts pointed toward concentrating material from sea water arose from World War I indemnity against Germany. You may recall this indemnity, which incidentally was never collected, was very large and was to be payable in gold. The eminent German chemist, Dr. Fritz Haber thought there was some possibility of recovering the required gold from sea water. He carried on various oceanographic investigations and found the average concentration of gold in sea water to be only about 0.004 micrograms per liter. This is very small, indeed, but there is a little bit of gold there and there is a great deal of ocean. There was plenty of gold available for paying the indemnity if it could just be picked out of its watery storehouse. Haber tried to devise a method for recovering metallic gold from these very low concentrations but he was never successful. However, there is visible evidence that there is gold in sea water because the Dow Chemical Plant at Wilmington, North Carolina, where they are recovering bromine as mentioned above, has, more or less as a stunt, recovered a very small amount of gold in connection with the bromine recovery. The cost of recovery was far greater than the value of the gold, so the matter was never pursued beyond the first demonstration. In connection with this, however, a very interesting proposal was made several years

ago by the late Dr. Colin Fink, then Head of the Division of Electrochemistry at Columbia University. By very careful control of electrical potential gradients Dr. Fink found that it was possible to plate out selectively almost any desired metallic element from an aqueous solution. He made the suggestion—perhaps seriously, perhaps not—that ocean liners, by maintaining the appropriate potential gradient between the propeller shaft and sea water, would be able to plate out substantial amounts of gold on the propeller blades during every ocean crossing and thus perhaps pay at least the out-of-pocket expenses. I do not think anything ever came of the idea, but it is an interesting speculation.

It is probable that some of the biochemical reactions I have been discussing are of the same general character as these base-exchange reactions I have just described. But we do not have a detailed understanding of even the inanimate base-exchange phenomena, much less those that take place in the biological systems. It is also almost certain that some aspects of electrochemistry enter into the biological reactions; but merely saying that does not mean that we really understand them. This new frontier will welcome new researchers with open arms.

With the evidence of nature at hand and with examples of man's recent efforts toward utilizing dilute resources, one can visualize some distinctly new composite processes in the future, utilizing sea water or brines or various other mineral bearing sources for the supply of many of our minerals. There are certainly at least a dozen minerals in sea water which we would very much like to recover at economical cost, and we could do so if we could get a combined process that would handle them all with one throughput of the material. From what I have observed, the traditional chemical processes, even the base exchange ones, will not suffice, for with such processes each element has to be handled quite separately, and the efficiency of recovery is not very great. We badly need to find out just what the individual molecules do in the biochemical organisms which pick one molecule out of a million and take it into their structure for their own purposes. If we can do this, there is a possibility of developing a process in which the input would be sea water; the output would consist of a dozen different concentrated and well separated minerals. Probably a most valuable byproduct would be fresh water. However, we have to learn a great deal more than we know now before we can accomplish this.

Perhaps a disproportionate amount of attention has now been given to the sea and the material it contains. There are many valuable materials in low concentration in the solid crust of the earth. I will give you one striking example. The average granite which makes up a very large proportion of the surface of the earth contains about 4 parts per million of uranium and about 12 parts per million of thorium. If this uranium and this thorium could be effectively extracted and used in a nuclear power reactor, then that uranium and that thorium could produce energy equivalent to the burning of about 50 tons of coal. Thus, the raw material for essentially an infinite amount of power for the present and future civilization is almost literally under the feet of almost everyone. But we do not have the ability as yet economically to extract the uranium and thorium from those very dilute sources. We need to develop the clever chemical pickpockets that will go in and retrieve those few parts per million in a practical and an effective way.

All these chemical processes which I have mentioned or suggested have one characteristic in common—they are highly *selective*. I have been laying a great deal of emphasis upon the abiilty to concentrate materials from dilute sources but there are other areas where the selective processes have unique advantages. Here, again, nature is pointing the way but is not yet telling us how to get to the goal.

As far as we are concerned, the most important chemical reaction in nature is that of the photosynthesis. It is the basis of all living matter. In the process of photosynthesis, plants take in sunlight, carbon dioxide and water, and form the chemical compounds which make up the plants and eventually ourselves and other animals. Some elements other than carbon, oxygen and hydrogen are involved but the basic, organic reactions are built around those three important elements. And the process is highly selective. Through the plant catalyst, chlorophyll, only those reactions take place which are useful in building up plant substances. In the laboratory, if an organic chemist, with man-made processes, takes raw materials like that and begins carrying out organic reactions, he usually gets a whole variety of "goos and gunks" a great many of which he does not desire and which are not useful. We have not yet been able to achieve any-

thing like that selectivity of organic reactions which characterizes organisms of nature.

Of course, over a number of years, there has been extensive study of the kinetics of photosynthetic reactions. This has been greatly accelerated within the last decade since radioactive tracers have become readily available for research work. A great deal more is known of the details of the photosynthetic process than was true ten years ago, but we still have a long way to go. Here, again, I think it is going to be necessary for us to get closer to the reactions which take place in individual molecules than we have up to the present. Only then will we be able to get a real insight into the kinetics of what really takes place in each of these minute steps which nature, in some way, has been able to evolve.

When we do really learn "What makes the grass green," new vistas will again open. Although we still have great supplies of the fossil fuels (coal, oil and petroleum) they certainly are only finite in extent, and the world demand is rising at a frightening and exponential rate. These fossil fuels came from the plant reactions, that is, photosynthesis, which was carried on one or two hundred million years ago. We are dipping into that fossil storehouse very rapidly and we are doing nothing to replace it. When we truly understand the photosynthetic process, however, it is entirely conceivable that we will be able to carry it on artificially, efficiently and rapidly without the use of biological materials and thus be able to produce all of the liquid and solid fuels that we will need in the future with only the materials at hand—sunshine, carbon dioxide and water.

But, even this is only the beginning. That portion of the radiation spectrum that is sunlight which is used in the natural photosynthetic process, is only one octave out of the known 58 octaves of electromagnetic radiation, with wave lengths that extend from the very short and penetrating cosmic rays on up to the long radio waves. Are there possibilities, as yet unknown, of chemical reactions which could produce useful substances which might be induced by or associated with some of those other 57 octaves of radiation? What new reactions can be induced by streams of neutrons, which have characteristics similar to electromagnetic radiation? To date answers to those questions are very incomplete. There must be a great deal of intensive work in the field of a new radiation chemistry before we can visualize the possibilities. As nuclear powerplants come into widespread use—which they will in various parts of the world very soon and in the United States before many people realize it—a tremendous amount of gamma and neutron radiation will be available at very low cost. Can this radiation be used to promote or to carry out new chemical reactions that we have never even dreamed of yet? This is worthy of a great deal of investigation and expenditure of effort. We will only determine the answers when we learn how individual molecules react.

Obviously, it is a bit unsporting to suggest all these things which need to be done and then fail to indicate any constructive approach to the solutions. I am not competent to give any detailed guidance and advice. However, I would like to point out a path of progress which, in the past, proved essential and critical in one other most important scientific area—nuclear physics. The understanding of the structure of the atom and the whole general field of nuclear physics made relatively little, solid progress until the researchers were able to observe the effects and the reactions of, literally, individual particles. The Wilson cloud chamber, the Geiger counter, the tracks on the photographic plate, the various scintillation counters were developed into tools for observing the actions of the individual, minute basic particles, such as electrons, protons and neutrons, which make up the structure of individual atoms. After those tools were at hand, progress came very rapidly, but as long as the physicist's work had been confined to dealing with 10^n particles in individual samples (^{n} being very large), their progress was very slow. The chemist is still in the state of dealing with tremendous numbers of molecules and atoms in even his smallest sample and hence, he is not able to arrive at the understanding of the actions of individual molecules which is probably necessary if we are ever going to be able to first imitate and then improve on nature in this pickpocket (highly selective) chemistry.

Is there any hope that the chemist may devise an experimental tool which would be analogous to the great breakthrough of the nuclear physicists a few decades back? I am not sure there is but I do have a suggestion.

During the past few years the physicists, in connection with studies of atomic and molecular resonance, have developed the technique of "molecular beam."

In a molecular beam, one observes the effect of the electromagnetic radiation of the trajectory of the molecule. Some molecules can be detected with a sensitivity of one per second, and the observation of a few thousand a second is easy.

Would the mere detection of individual molecules open the way to a better understanding of detailed kinetics of the chemical reaction of individual, or a few molecules? I am not qualified to answer, but it certainly would be interesting to find out. There might be something there.

If the mere detection operation should prove to be significant, perhaps we should re-investigate a much older, highly sensitive detection device—the dog's nose. A clever dog that can pick out the trail of his master from that of many other humans must be detecting one molecule of olfactory substance out of at least a billion. By what combination of chemistry, electrochemistry and molecular resonance does the dog accomplish this feat? There has been much speculation and some experimentation but no definitive answers. It would be interesting to see what a team of physicists, chemists, biochemists, and biophysicists could do with such a new and comprehensive exploration. The results might be fruitful in many directions.

To summarize. There are a great many chemical reactions which occur throughout nature which are of the pickpocket variety—stealthy, difficult to observe and highly selective—which are not yet understood and which have not been duplicated in the laboratory. Many of them appear to have unique possibilities for practical application, particularly in the winning and rewinning of mineral resources from very dilute sources. Within the next few decades, the world demand for minerals, as well as energy, will undoubtedly rise by many fold. Improved technology to meet these demands must be developed in the near future. Perhaps the key to success in picking the one desired molecule out of a million will be found in intensive investigation of the basic phenomena of living matter. This is the traditional domain of the biochemist, but he will need the help of other scientific specialists. It would appear that a substantial and comprehensive national and industrial research program attacking the complicated problems from many angles would be fully justified—not in some distanct future, but now.

Admittedly, there has been much speculation in this paper—but that is the stuff of which progress is constructed. To quote an eminent British scientist, A. V. Hill, "It is dangerous to speculate too far, but it is foolish not to speculate at all."

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Water requirements

Dr. FURNAS. In my opinion, the third great question in the natural resources problem is, "What makes it rain?" Many of the wilder and bloodier stories of the early West centered around the battle for the old waterhole. Particularly in our own Southwest, this situation still holds and is getting even worse, although we ordinarily do not any more carry on the battle with guns.

By means of dams, wells, irrigation ditches, and even feeble attempts at rainmaking, we try to solve our water problem. We are losing ground steadily as more and more people move into that region, bringing increased industrial and agricultural demands. The situation in

other parts of the world where millions and millions of destitute and hungry people live is even worse.

1. *Fresh water from salt water.*—Yet while we are continually starving for water in many important parts of the world, the shores of almost every nation are lapped by the infinite supply of the ocean. Unfortunately, the ocean contains salt and such water does not fulfill the needs of most of modern industrial civilization. How can we get fresh water from salt water?

Our Department of the Interior has a multifaceted development program to devise processes for getting fresh water from salt or brackish water but it is based upon old knowledge and old technology. One can say that the program is proceeding satisfactorily but results indicate that the processes are not now and will not be economical in the true sense of the word unless some new factors are added. At the present time the cost of fresh water produced by these methods will be 5 to 10 times that which can be practical, except under the most unusual economic circumstances.

2. *Rainmaking.*—Parallel with this, there have been several empirical approaches to rainmaking by seeding clouds with dry ice or by using silver iodide generators on the ground. Success with these experiments has been quite indifferent and there is no prospect of very much improvement as long as we confine ourselves to this purely empirical approach.

While we are struggling with these empirical methods based upon past knowledge, we still do not have the answer to the question, "What makes it rain?" Stated another way, we do not yet understand the minute physical forces that are involved when two fog droplets coalesce and then coalesce with some other droplets, finally to form a drop of rain. We know the overall conditions for the formation of rain droplets under severe temperature gradients such as occur in a thundercloud, but this is only one of the special cases of the rainmaking process. If we did know exactly how nature causes the fog droplets to coalesce, I feel certain it would help tremendously in developing new and economical industrial processes for recovering fresh water from the sea and brackish waters. It might also point the way to really effective local control of weather. Yet there is almost no research going on in this important field of the physics of surfaces involved in droplet formation.

Importance of basic research

In summary, then, because of the absolute necessity for us, as well as the other nations of the world, to solve the problems of maintaining an adequate supply of the natural resources—energy, minerals, and water—I feel we should have increased emphasis in our national research program upon the search for the answers to those three questions: What makes the grass green? How does the oyster get its copper? What makes it rain? The problems themselves, of course, would be phrased in such more erudite titles but I do feel that those questions point up the problem. Perhaps there are other questions that are even more important, but those are typical of our area of ignorance.

I have a suggestion to make and it involves the National Science Foundation. That Foundation, as you know, has over the past sev-

eral years been carrying on magnificent work in encouraging and supporting basic scientific research in the physical sciences as well as in scientific education. In the research area, as a matter of policy, it lays great stress on the fact that it does not dictate or guide research programs or areas of research. The Foundation gives objective consideration to proposals which scientists submit for support of particular research projects which they want to undertake. In the field of the physical sciences, there are not many limitations of subject matter. The theory back of this policy is that you cannot direct basic research. You can only give the research man the opportunity, through support, to follow his own individual interests and propensities. Of course, nearly all of our scientific knowledge of the past was developed from this random approach. It is virtuous but is it sufficient?

"Vectored" research

Without attempting to direct individual projects, and certainly without attempting to dictate the individual research man's program, I feel that a small shift in the policy of the National Science Foundation might aid very materially in arriving at early answers to those three important questions. If a certain proportion of the funds available to the National Science Foundation were earmarked for the support of research in those or similar carefully selected areas, and if it were made known that money would be available for those but that those particular dollars would not be available for other projects, I think we would find a number of scientists who would be willing to come forth with some really potent ideas which might quite readily lead to worthwhile results. Indirectly, of course, this would be lending direction to the lines of research but it would not be direction in detail and it certainly would not be dictation. (I call it "vectoring" rather than "directing" research.) It would not be necessary to set up any new organization to handle that sort of problem and I doubt if it would take very much more money, in proportion to the national expenditures. But I feel that the problem is serious and worthy of whatever effort and expenditure may be called for. I greatly fear that the random approach, as contrasted to such a lightly directed approach, as I suggest, will not provide the answers to our basic natural resources problems in time to avoid serious international mishaps.

There are those who contend that such problems should be dealt with only by industry because, obviously, successful results will lead to production which in turn will lead to profits. However, our basic knowledge is so sparse that immediate application cannot be guaranteed and industry quite rightly, in my opinion, is not justified in spending any large number of dollars on this type of research at this early stage. I feel that it is a national problem which calls for a national approach at this time. Industry should pick up the applied research and development at a somewhat later date.

In order to point up the importance of solving these problems as rapidly as we can, I would like to quote from Dr. Harrison Brown of the California Institute of Technology in a paper of his, "Resources of the World in 1956":

> As our dependence shifts to such resources as low grade ores, rock, sea water, and the sun, the conversion of energy into useful work will require ever more intricate technical activity, which would be impossible in the absence of a variety of complex machines and their products—all of which is the result of our intri-

cate industrial civilization and which would be impossible without it. Thus, if a machine civilization were to stop functioning as the result of some future catastrophe, it is difficult to see how man would again be able to start along the path to industrialization with the resources that would then be available to him. We are rapidly approaching such a "point of no return."

That, Mr. Brooks, is my statement.

Mr. BROOKS. Thank you very much, Dr. Furnas. It is a very challenging and enlightening statement.

Dr. RUSSELL. Mr. Chairman?

Mr. BROOKS. Dr. Russell?

MINERAL POLICY

Dr. RUSSELL. In complete support of some of the points that have been made by Dr. Furnas, I would like to present for consideration of the committee the presidential address given by Ian Campbell, chief of the California State Division of Mines, entitled "The Industrial Minerals, Research, and Mineral Policy." May I offer this for the record?

Mr. BROOKS. Yes.

Dr. RUSSELL. It supports the idea completely, the vast resources of the oceans and also of granite.

Mr. BROOKS. Let it be put into the record.

(The document referred to is as follows:)

THE INDUSTRIAL MINERALS, RESEARCH, AND MINERAL POLICY[1]

(By Ian Campbell, Chief, California State Division of Mines)

Some of you who are present here tonight may have memories long enough to recall that it was in 1935—twenty-three years ago—that the geological sciences were last represented in the presidency of the Pacific Division. In that year, the late Bailey Willis of Stanford University addressed you on "The living globe". It was a timely topic, for certainly in the succeeding quarter century, we have witnessed some lively doings on our globe. In this period a great deal has been happening, in the world, in science, and in geology. So, when I faced the difficult question that is part of the price one pays (if I may put it this way) for the privilege of a presidency—namely, the question of "what topic shall I discuss for my presidential address?", I naturally thought of "a review of geology in the last quarter century." How easy that would have been for me; but how dreary for you! Resolutely I put this temptation behind me and began to cast about for a topic that would be more challenging for me and perchance more interesting for you. Alas! I was still casting about for the right topic when your program chairman reminded me that "Time is up; we need a title right now; you needn't know what you are going to say—just pick a title broad enough so that you can include anything you may want to discuss". Well—it is obvious that I picked myself a broad title: "The industrial minerals, research, and mineral policy".

As a matter of fact, I was rather congratulating myself on the breadth of this title, until I came to realize that anything that has breadth is likely also to have length; and that what I had actually done was to give myself a rope long enough on which to hang myself. Certainly anyone who dares to express himself on mineral policy these days is going to find one group or another eager to hang him. If he speaks for higher tariffs, then the free-traders generally, and the internationalized producers of minerals in particular, will be out to hang him. If he speaks for lowered tariffs, the domestic producers will be the ones to fashion the noose. If he asks for subsidies, the consumers will be against him. Indeed, if there be any virtue at all left in my title, it is only that I did have sense enough to approach the gallows cautiously. I

[1] Address of the retiring president, Pacific Division, American Association for the Advancement of Science, at Utah State University, Logan, Utah, June 16, 1958.

propose to start with the subject of industrial minerals, something that I do know a bit about; from there I plan to go on to a discussion of research, something that interests me greatly, although I have still a great deal to learn about it; and only after that do I propose to take the fatal plunge into mineral policy.

So, now, let us take a look at some aspects of the industrial minerals. I do not intend to, and indeed I shall not exclude metalliferous ores or petroleum from this discussion. I am only taking the industrial minerals as a plane of reference because of certain interesting circumstances with which I am familiar. For some perhaps I should define what is meant by industrial minerals. These are the minerals for a long time designated by economic geologists as "the nonmetallics". These were the minerals sought not for their content of a metallic element as we seek galena for its content of lead or zinc-blende for its content of zinc, but minerals that were sought for some industrially useful property that was perhaps inherent in the mineral just as it came from the ground (such as graphite or diamond or native sulfur), or which could be developed by a treatment that did not require reduction to an element (such as the conversion of limestone and shale in a kiln into Portland cement). The nonmetallics were a large and diverse category, including such common things as sand and gravel and clay, and such relatively rare minerals as sheet mica (for dielectric uses) and zircon (for high grade refractories). The nonmetals—indeed the very name implied it—were rather looked down upon by economic geologists and mining engineers of the past generation. Some still look down upon them even though in terms of our national economy the value of the annual output of the industrial minerals in each year since World War II has exceeded by several millions of dollars the value of the annual output of the metalliferous minerals.

The industrial minerals, it is said, have been "the poor relations" of the mining world. They have lacked the glamor of the metals. One might say that in achieving their present economic importance these minerals—more properly the people who have been working with them—have had "to come up the hard way." They have actually had something of an inferiority complex. I am not going to say "suffered from an inferiority complex" because actually I believe that a small amount of inferiority complex is a good thing, whether for a man or for an industry, or indeed, for a nation. Properly applied, an inferiority complex can be far more of a stimulus than a handicap. It destroys smugness and prevents boastfulness, and generally contributes to the kind of humility that makes for good neighbors. I am hinting indeed that the United States has perhaps been overly boastful about its vast production and about its vast resources, particularly of the metalliferous minerals. It doesn't take much of this kind of boastfulness to ruin a great deal of effort toward sincerely designed good neighbor policies.

To return to the industrial minerals: there have been no (at least few) bonanzas among industrial mineral deposits; there have been no rich strikes; there have been no easy-going profits. The analogy has been cited so often it is now almost a cliche, but the industrial mineral industry still deserves to be compared with our modern packing industry, which as you know claims that in order to make any profit it must use "everything but the squeal of the pig." This indeed has been one of the major contributions to mineral development that has stemmed largely from the industrial minerals—the recognition of the importance of by-products and the development of methods to handle them. Parenthetically, it is of interest to note that in recent years, just as nonmetals have graduated to the more positive and dignified term, "industrial minerals," so have many by-products been graduated to the more dignified term of "co-products"! Let me take my first illustration from the USSR, both because it will give credit where credit in this case is surely due, and because it will illustrate some other factors of mineral economics.

Before the first world war, Russia had obtained the bulk of the phosphate fertilizer, so necessary to her great wheat-growing areas, from the rich phosphate deposits of North Africa (Algeria and Tunisia). During that war, Russia was effectively isolated from Mediterranean shipping, and in the last years of that war considerable portions of the Russian population were virtually on a starvation basis, largely because of the reduced crop yields resulting from the lack of phosphates. Accordingly, one of the first developments in the Soviet first five-year plan was a program to develop domestic sources of phosphate sufficient to assure Russia freedom in her own agricultural economy. At that time no

high-grade rock phosphate of the type that we know here or that was available in North Africa, was known in Russia. But in the Kola Peninsula, that far northern projection into the Arctic lying just west of the White Sea, were large bodies of a curious rock—hitherto just a petrologic curiosity—composed of two otherwise rather rare minerals: apatite, a calcium phosphate, and nepheline, a high-alumina, potassium aluminum silicate. Up until this time neither mineral, either singly or together, had been of any industrial importance. But apatite is a phosphate mineral and with proper treatment can be converted to the superphosphate desired by agriculture. This the Russians set out to do, and the building of the Leningrad-Murmansk railroad (so important to the Allies during World War II) was one of the elements in that program. But to mine this rock, use the apatite, and allow the nepheline which constituted nearly 50 percent of the rock to pile up as waste, would be highly uneconomic. Soviet scientists recognized that nepheline had qualities which for many purposes made it superior to feldspar in ceramic applications. The result: a new industrial mineral was born out of what had been a museum curiosity. And in this country it was not long until the American Nepheline Corporation was formed to mine extensive deposits (in this case, however, unassociated with apatite) in Ontario. Next let me turn to an illustration much closer to home and as recent as last year.

Sand and clay are important and fortunately rather wide-spread industrial minerals. Unfortunately in California, despite our richness in many mineral deposits, sands and clays of industrial quality are all too scarce. Such as do occur are mostly confined to one geological horizon, the early Tertiary. The Ione formation in the foothills of the Sierras is of this age and locally has produced some good clays, but extensive sections of Ione clay have been regarded as worthless by the ceramic industries because of their high sand content. Just a few years ago the Gladding McBean Company, one of the principal producers of ceramics on the Pacific Coast, and the Pacific Division of the Owens-Illinois Glass Company, jointly undertook a study of portions of the Ione formation with the idea that, by developing suitable beneficiation techniques, material that had been worthless either as a clay or as a sand, could be sufficiently purified as to yield both a commercial clay and a commercial glass sand. And within just the past year this has become an accomplished fact. One company does the mining; the other one does the beneficiation; Gladding McBean gets the clay; Owens-Illinois gets the glass sand; and California, which collects taxes from both, is happy to see what had been worthless ground turned into a valuable industrial mineral asset. Besides the tangible profits that are accruing to both companies and to the state, there is the important intangible value that develops from an "entente cordiale" between two companies which otherwise might have been competitive. Does it take much imagination to extrapolate such a situation to the case of two countries, which to the advantages of both might share mineral resources and mining techniques rather than hoarding them or fighting over them?

One more illustration I want to take from California, and once again I wish to review a problem that was of great concern to the United States during the first world war. Phosphorus is not the only important "fertilizer mineral." The "big three"—as they are sometimes referred to—are phosphorus, nitrogen, and potassium. The United States has long been well off in phosphate minerals; nitrogen we can now get from the air (as well as from mineral deposits in Chile); but up until World War I we had been dependent on mineral imports from Germany for the potash vital to our agricultural industry. When the body politic gets hurt in the stomach, things are apt to happen! Even so, they happened slowly. We subsisted—barely subsisted—for a number of years on desperate measures. We dredged kelp off the California coast and burned it, to recover its small yield of potash; we installed the first bag filters on cement kiln stacks, in order to get the potash that was going off in the dust. The American Potash and Chemical Corporation undertook to extract potash from the brines of Searles Lake. (Only later came the discoveries in the Carlsbad area of New Mexico which have so greatly increased our potash production and our potash reserves.) Searles Lake is no lake in the ordinary sense. In the first place, it is a "dry lake"—such lakes are by no means uncommon in our Southwestern desert areas. But Searles dry lake is unique, geologically, in that it consists of a thick body of salts of which NaCl is only one, and among which are a number of otherwise extremely rare minerals—various combinations of Na, K, Mg carbonates, and sulfates. The geology, mineralogy, and chemistry of

Searles Lake is an extremely interesting story in itself, but I must confine myself to the industrial mineralogical aspects. This unique salt body has rather high porosity and the pores are everywhere filled with brine. The American Potash and Chemical Company does not mine the solid salts; it mines the brine—by means of wells and pumps. And from this brine it originally extracted potash and, as an important co-product, that element of which we have been hearing so much in this nuclear age, boron. For several years potash salts and borax constituted the products. But in the course of evaporating and crystallizing out these salts from the brine, it became apparent that other products could be obtained by going just a little further in the extractive process. Salt cake (sodium sulfate), soda ash (sodium carbonate), and phosphoric acid have new become important co-products. And—surprising to many—Searles Lake emerged during World War II, just when we needed it most, as our principal producer of lithium. Bromine salts are also being produced, and only recently we have learned that the Searles Lake brines constitute our nation's greatest reserve of tungsten—something we had thought of as exclusively the property of the hard-rock miner! Tungsten is not now being extracted because at present prices and with presently known methods of extraction, it could not be economically produced. But small increases in the price of the metal, or small improvements that would lessen the cost of extraction could readily add tungsten to the list of co-products from this remarkable "mineral deposit."

I have referred to Searles Lake as a unique mineral deposit, and this it truly is. Even more unique (if anything can be "more unique"!) is the process of extraction, or as a miner might say, "beneficiation." The now successful plant process for the Searles Lake brines is the result of a great deal of painstaking research—research which met the discouragements that research into a new and untried field not uncommonly encounters, but research that today has well demonstrated both its scientific and its economic soundness.

Research in the field of the industrial minerals has been responsible not only for turning worthless rock and fossil brines into ore, and for developing unexpected by-products from sources established for other needs, it has led to synthesis—from easily and abundantly available materials—of industrial minerals with which nature has provided us with a far too scant supply. Take for example cryolite (sodium aluminum fluoride), a mineral known from only two or three localities in the world and in only one of which does it occur in more than pound lots. In this one occurrence, on the southwest coast of Greenland, it is fortunately found in millions of tons; for this mineral is the foundation of the aluminum industry. Cryolite provides the bath in which the far more common, but more refractory ores of aluminum are melted and electrolyzed to yield the metal. Thus cryolite is necessary for the celebrated "Hall process" of extraction which has made the aluminum industry what it is today. Although, in this process, only relatively small amounts of cryolite are consumed, the one natural deposit of this mineral has now been virtually exhausted. Fortunately for all the world—with which Greenland had for many years shared her unique treasure—synthetic cryolite can now be prepared from other much more abundant and widely distributed minerals.

Diamond is today far more important as an industrial mineral (because of its supreme hardness) than it is as a gemstone. The United States has always been, and I daresay always will be, dependent on Angola and South Africa for its supply of natural diamonds. But now, after more than a century of abortive attempts by scientists, engineers, philosophers, frauds, and magicians, we at last have a practical method for synthesizing diamonds from that abundant raw material, coal. One of the trickiest of all minerals to synthesize, mica, can now be made as the result of patient and imaginative research in federal and other laboratories. And we are thus no longer so dependent upon India and Brazil as we once were for this mineral which throughout the war and for some time after stood practically at the top of the list of "critical materials."

Before this audience there is certainly no need to go into any extensive discussion of research. As scientists we are of course all for it—it is our life-blood. And I have already indicated that research has been the life-blood of what are today many of our great mineral industries—although I regret to say, in passing, that in the year 1957 the mineral industries spent only 2 percent of sales on research, compared to the chemical industry which spent 4 percent, and the pharmaceutical industry which spent 5 percent. Nor do I see any need, before this group, of getting involved in the semantic difficulties of attempting to define or to discriminate between fundamental and basic and applied research.

All research, to the extent that it is concerned with providing us with new or better knowledge, is research and is worth doing. The pragmatic test of research may be immediate or long-delayed (it was 60 years from the discovery of radioactivity by Becquerel in France to the start of the uranium boom in the United States which, if the figures could be released, would now be recognized as the greatest mineral boom the world has ever seen). Should we even want to apply the pragmatic test to research? If scientists are dedicated to their science, then research should be worth doing for its own sake regardless of tangible rewards, immediate or delayed.

Since last October almost every speaker who mentions science, or research, has paid obeisance to Sputnik. I too will pay my brief obeisance here and now to this remarkable scientific and engineering achievement of the Russians; and in the same breath I will say that the saddest of all reasons for the support of science and research is that of "keeping up with the Joneses." If science and research have fundamental values then they deserve support for these fundamental values and properly for these alone.

As the result of the spectacular development in satellites, "moonwatching" has become a serious avocation and missilry has become an especially engaging field of science. As a geologist I am highly in favor of reaching as far into space as we can, for inevitably in so doing we will learn much about the earth. But I cannot help but feel that with the great hue and cry towards "outer space" we may be neglecting important exploration that needs to be done beneath our very feet! Should it be any more intriguing to send recording instruments into the relatively unknown areas just beyond the earth's atmosphere, than to send recording instruments down beneath the first of the discontinuities in the earth's structure? The so-called Mohorovicic discontinuity (immediately beneath it we know almost nothing of the underlying material) lies only some 20 miles beneath the continental areas—less than half this figure, beneath the oceans. We are already conducting mining operations at depths of about two miles, and oil wells have been drilled nearly four miles down. Ten years ago the farthest up we had reached (with a V–2), was a little over 100 miles. Now Vanguard has gone 2,500 miles! Is any more of a scientific and engineering breakthrough required to go from 100 to 2,500 miles up, than to go from four to 20 miles down? Our artificial satellites are sending back information on temperature, density, and radiation. This is exactly the kind of information that we need from these unknown depths in the earth. Such information would be of intense scientific interest, and it could be of great practical value, for out of it we might learn what triggers earthquakes, how granite is formed, and whence the lava is generated that causes volcanoes. Here is research that should be done, and I hope will be done soon. But I hope it will not be done just because we think if we don't get at it, the Russians may "beat us to it"! And right here it deserves to be emphasized—as indeed it cannot be emphasized often enough—that although Americans have done well enough in the research that leads to "know-how", we could and should do far more in the research that leads to "know-why."

Inasmuch as I seem to have reached a "preaching stage" in this discussion, perhaps it is time that I get onto this matter of mineral policy, although I doubt that preachers are any safer from hanging than are scientists! In order that, for the moment at least, I may not incur the wrath of my friends in either the nonmetals or metals industries, I shall take my first illustration of mineral policy from the field of petroleum. Furthermore we are all directly concerned with petroleum, whether as a source of heat for our homes, or of fuel for our cars—to say nothing of its many other equally vital uses. A distinguished petroleum geologist told me a few weeks ago that the "extractive cost" of a barrel of oil at the well head in Saudi Arabia is about a nickel. Here in the United States, it is about a dollar. A dollar a barrel versus a nickel a barrel. If Americans, as a nation of automobile users, desired to apply the rule of "the greatest good to the greatest number," it would seem that we should bring in all of that nickel-a-barrel oil that we possibly can and thereby lower the cost of living, or at least the cost of driving, to our benefit. Moreover, in doing this, might we not also enjoy the satisfying feeling that we were at the same time contributing to our national defense? We have only so much oil in the ground and we have already taken a lot of it out. Producing, as we have for many years, more than half of the world's requirements for petroleum, we now have left only about 15 percent of the Free World's reserves. We would have real trouble in fighting another big war with just the oil still available from domestic sources. Why not, therefore, import all the foreign oil we can while the importing is still good (it might get cut off at

some time in the future), and save own own oil for the time when we may desperately need it?

These are telling arguments, but before we accept them at full face value, let us look at the other side. The domestic petroleum industry is one of our largest and most efficiently functioning industries (as the result of heavy emphasis on research all the way from exploration to production and processing). If nickel-a-barrel oil comes here in large quantities then large segments of our domestic industry may have to go out of business—industry that is employing thousands of Americans, industry that is paying millions of dollars in taxes, and millions of dollars of dividends. Is this good? And what of national defense? Just knowing that we have reserves of oil in the ground would do us little good for either an immediate military or industrial effort. We must have equipment installed *and* operating in order to get the oil from the ground and we must have men familiar with operating that equipment—obviously we cannot accomplish this by having the oil wells and the petroleum engineers all in Saudi Arabia and Venezuela!

If I have pointed up the problem of petroleum policy it is only because petroleum is a more familiar mineral commodity to most of us than are many of the metallic and the industrial minerals. Many of these, even though our tonnage needs are small as compared to petroleum, are equally vital to our economy. And the problem of supply is for many much more acute than is the supply of petroleum, for a good number of vital minerals are not found in minable concentrations within the United States. For these we are entirely or almost entirely dependent upon foreign imports. I know that there is a general feeling that "if we want some mineral badly enough, we need only raise the price high enough, and we'll get it—from domestic sources." For some things this may well be true, as it was true for magnesium during the war, and more recently, for uranium. But for some things this is just not true: tin for example. The price of tin could be raised to dollars a pound, and the amount of domestic tin ore that would result would be insufficient to supply even a tiny fraction of our needs. So what must we do to get tin? We must be friends and *keep* friends with the tin-producing nations. We can do this by reasonable and consistent reciprocal trade agreements; we cannot do this by unilateral deals, by making sudden demands and following these with sudden cut-backs, by forcing feast and then famine upon sister nations.

Whether the problem is one of domestic versus foreign production, or of needed imports, it is clear that there are no easy solutions. Mineral policy right now, and probably for years to come, must be a policy of compromise. To some, I know, "compromise" is a nasty word. We speak in hushed tones of "comprising situations." But "a situation that calls for compromise" (and calls openly) is something else again. Here "compromise" is a word of dignity, and presents a situation that should attract the best efforts of our economists, mineralogists, and statesman-politicians. Intelligent compromise can only be achieved on the basis of thorough knowledge and understanding. Alas! Geologists and mineralogists do not yet know nearly as much as they would like to know about the ultimate origin or the cause of distribution of ore deposits. This we do know: ours is a rather asymmetric world, geologically. The rocks that immediately underlie the great ocean basins are basically different from those that immediately underlie the continents. And within the continents, there are vast differences in the details of the rocks, and associated mineral deposits. Why was almost all of the world's cryolite concentrated in a few acres of ground at Ivigtut, Greenland? Why is perhaps 90 percent of the world's borax concentrated in southern California? We geologists wish we knew the answers to such questions. But while the answers are being sought, we must live with the facts: that no nation is self-sufficient in terms of the mineral resources required for 20th century civilization. Therefore when a nation has 99 percent of this, or 75 percent of that, has not nature herself presented that nation with a trust that is certainly the concern of all the world, and which thus should be treated as a trust by the nation that by accident of geology and geography has been presented with such a treasure? Ideally, yes. But practically, we still live in an age dominated by the principle of "finders keepers", and if we find something first, it's all ours, to do with just as we very well please.

Must we always live within the horns of these dilemmas? Must we continue to vacillate between the theoretical logic of "one world" and the free trade principles that this implies, and the practical necessities that seemingly call for high tariffs? Nor is that vacillation any free-swinging pendulum; every

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time it moves, it generates friction, and generates friction in an environment so tinder-dry that a small spark can start a war. Too many wars already have been fought for mineral rights. Must we have more?

There is, I think, a way out. It is probably a slow way out; but I think it is a sure way out. It is likely to be slow for in part it depends on basic research that is still to be done; and the time is as unpredictable as it is for any basic research to reach its objective. And there are many objectives. I will mention only one: can we geologists learn successfully to synthesize granite in order that we can better learn how to take it apart?

What for, you may well ask. Well in the course of the fractionation of magma to produce granite, that has gone on in our continental areas, many valuable components have become relatively concentrated in the granitic rocks. In 100 tons of average granite, there are about 8 tons of aluminum, 5 tons of iron, 3 tons of potassium, 1200 pounds of magnesium, 1200 pounds of titanium, 180 pounds of manganese, 70 pounds of chromium, 40 pounds of nickel, 30 pounds of vanadium, 20 pounds of copper, 10 pounds of tungsten, 4 pounds of lead, as well as significant amounts of boron, lithium, and similar materials. This is all very fine, you will say, but most of these elements are "locked up" in the form of silicate minerals which are difficult chemically and expensive economically to decompose into their constituents. Quite so. But an average granite also contains about 12 ppm of thorium and 4 ppm of uranium, and these 16 ppm of radioactive elements represent the fuel equivalent, for 100 tons of granite, of 4500 tons of coal. Furthermore, the thorium and uranium, recent research has shown, are not locked up wholly in refractory minerals; a large share is in rather easily extractable form. It seems not unlikely that more than enough nuclear fuel can be obtained from granite to furnish the energy required for its own recovery plus enough surplus to accomplish the extraction of many of the valuable elements I cited a moment ago. When this is done, we may have achieved the nearest approach to "perpetual motion" that the world has yet seen, and we will have a virtually inexhaustible and widely distributed mineral resource, granite, to draw upon. To be sure, this is some distance in the future. We are not yet at the stage of considering nuclear fuel as economically competitive with other sources. But we are not far from that. The design of the newest British reactors, it is reliably reported, will provide electricity at 7 mills per kilowatt. This does not compare with the approximately three mills per kilowatt that Grand Coulee and Boulder Dam power costs to generate; the figure is directly comparable with some of our small and higher cost sources in the country, and it is certainly competitive with the relatively costly coal-produced energy on which the British have had to depend. When the time arrives, as it undoubtedly will, and perhaps soon will, that nuclear fuel can undercut conventional sources, then we are going to see such demands for thorium and uranium as are rapidly going to exhaust our presently known "high-grade" ores. Granite will be a next logical source, and the mining of granite for its nuclear fuel thus opens up tremendous vistas for by-products and co-products.

Another virtually "inexhaustible resource" is already producing minerals for us: the ocean—the "mineral sump" for all of the continents. Long ago, when gold was more sought after than now, we were sometimes dazzled by the figures quoted of the "jillions" of dollars of gold stored in the oceans. And it was true that, in a few areas, the concentration of gold in sea water was not far below the point where it might be extracted at a profit. If the price of gold should ever go, as it once did on the black market, to $90 an ounce, I daresay someone might start a successful gold mining operation in the seas off the coast of Australia! Much more important to us today than gold, and a much more realistic example of what is already being done to make the seas productive, mineral-wise, is magnesium. For a number of years both the Dow Chemical Company (in Freeport, Texas) and the Northwest Magnesite Company (at Cape May, Virginia) have successfully been extracting magnesium salts from sea water—so successfully, indeed, that "synthetic" or sea-water magnesium, has now to a considerable extent replaced magnesite mined from our continental deposits. Many other valuable constituents are present in sea water, and some day will be forthcoming as co-products or by-products of magnesia. It is of interest to mention here, perhaps, that the lithium oxide content of the Searles Lake brines, now an important source of this element, is only about .015

percent, which is not much different from the average "concentration" of LiO_2 in the earth's crust, viz., 0.013 percent.

It is high time that I brought together the three topics in my title: industrial minerals, research, and mineral policy. In thus summarizing, perhaps I can once again demonstrate that there is virtue in the old adage, "the whole is greater than the sum of its parts."

Trends in the field of the industrial minerals are pointing the way which may soon be followed by the entire mineral industry. In the past, prospector and producer alike have sought the rare and high-grade mineral deposits. Today the prospectors and producers of *industrial minerals* have successfully shown that the most effective mineral supply is best obtained from large, low-grade, and widely distributed deposits. This development has been made possible by *research:* research which has developed by-products and co-products from complex low-grade sources; and research which has made possible synthesis of rare minerals from common materials. *Mineral policy*, meantime, has of necessity been founded on the unhappy fact that the high-grade mineral deposits—the deposits upon which we have largely built our industrial civilization—are distributed according to what might be regarded as accidents of geology, of geography, and of history. With such distribution is it inevitable that mineral policy could never be entirely satisfactory nor wholly consistent.

Now, by prosecuting research with sufficient vigor, we can look forward to the time when virtually all of our mineral needs, including fuels, can be obtained from two virtually inexhaustible resources: granite batholiths and ocean water. Almost all nations have access to the sea; almost all nations have granite cropping out within their borders, or present at no great depth beneath a surface veneer of sediments. Thus almost all nations will have ready at hand those mineral raw materials which because of scarcity have been the source of so much conflict and so much unhappy compromise in the field of mineral policy. To speed this day we must vigorously prosecute mineral research: a job not only for the geologist and mineralogist, but for the engineering scientist, the physicist, the chemist and—recognizing that some of our most important mineral deposits are directly or indirectly the result of organic activity—the biologist. As scientists we can give our research no finer goal. For, when successful, we will have eliminated one of the major causes of war. For the present, however, mineral policy must be compounded out of knowledge and tolerance, and a recognition of the need for intelligent compromise.

Mr. BROOKS. We are happy to have it in the record.

Are there any further questions from anyone?

(No response.)

Mr. BROOKS. I think your statement sounds so complete that we are—when you find Members of Congress speechless, it is something unusual, I can tell you that. [Laughter.]

Mr. MOELLER. And he didn't sound as though he was out of breath, Mr. Chairman.

COMMENTS BY REPRESENTATIVE BASS

Mr. BASS. Mr. Chairman?

Dr. Furnas, I come from New Hampshire, which is otherwise known as the Granite State. We have a lot of granite up there and your remarks were particularly interesting to me. It certainly could mean a very far-reaching and interesting development as far as we are concerned up in New England, if we could ever learn how to develop anything out of granite.

Dr. FURNAS. Of course, this is the point, that we just don't know yet. I think we are a long way from knowing. But I think the laws of nature are such that they will allow us to do such things.

Mr. SISK. Mr. Chairman?

Mr. BROOKS. Mr. Sisk?

COMMENTS BY REPRESENTATIVE SISK

Mr. SISK. Sorry I missed part of your statement but I just came from a hearing in which we are preparing to spend many millions of dollars to develop fresh water in this country. I was very much impressed with your statement. If I had a question, Doctor, it would go to the extent of a little more direct and specific recommendations in this field. Now, as I understand you recommend possibly a little more concentration on some of these specific sciences dealing with this subject, but as I say having just come this morning from a hearing where an area of our country is desperately in need of, actually, drinking water. This happens to be for a large city out in the Midwest.

HOW RAIN IS FORMED

Dr. FURNAS. Might I take a few moments and explain a little more in detail the type of thing which I have in mind that might be solved if we had more fundamental knowledge.

First, if I might just review what the natural process is in terms of the formation and the activity of a thunderstorm. In that case, when thunderclouds form, you have a mass of humid air close to the ground. It is warmed by the Sun, and then it begins to rise to an area of lower pressure. The thunderclouds usually form between twelve to eighteen thousand feet. At 18,000 feet the atmospheric pressure is one-half of that at the surface. So you have a mass of moist air expanding. This is moist air where the water is in the form of vapor, not droplets. It is expanding into an area of one-half of the atmospheric pressure. As it expands it cools. As it cools, these cloud droplets or fog particles, if you want to call them that, begin to condense out. When they condense they release, relatively speaking, an enormous amount of energy. That is when 1 pound of water condenses from water vapor it releases approximately 1,000 B.t.u.'s which means it releases enough energy to heat 1,000 pounds of water by 1°. That heat release is the source of the energy of the violent winds that you get in thunderstorms. In this cooling process, as the air mass rises up to the area of half the atmospheric pressure the temperature becomes very low relative to what it was at the ground and you suddenly come to the point where you have supercooled droplets and they begin to condense into larger drops which fall as rain.

This coalescing into large drops occurs very rapidly in the thunderstorm because the temperature has come quite far below the condensation temperature. Hence, as the moist air expands into an area of substantially lower pressure, it releases a lot of energy, and this all goes on automatically. In other words, in the natural process it is not necessary to supply energy to make it rain; rather you get a large release of energy.

Now, let me call your attention to another phenomenon that perhaps some of you have noticed. Some airplanes have a cooling system where the air is sent through a so-called turboexpander, or expansion turbine, where the moving air, after it has been compressed by a compressor up forward does work and when it does work through this expansion turbine the temperature drops, just as the temperature drops in a thundercloud as it goes up to 18,000 feet. As the temperature

drops, if you are flying through rather moist air, you frequently find there is a cloud of fog droplets coming into the cabin, much to the chagrin of some of the passengers who think it is smoke. I have noticed particularly that elderly ladies get highly disturbed and the hostess has quite a job of assuring them it is not smoke but water vapor. She doesn't understand this, either, but this is what she has been told and of course it is true. If you had very large compressors and turboexpanders it would seem that you should be able to duplicate the action of the thunderstorm. Taking very large amounts of moist air, let us say, which had been saturated with the moisture at sea level by aspirating it through water, you could run it through a turboexpander such as used for cooling aircraft. Then it would appear that you should be able to condense out fresh water. But the trouble is that those little droplets do not coalesce. They just remain as minute fog droplets as they do in the airplane cooling system. However, in nature, the fog droplets do coalesce to form large drops even when you do not have the severe temperature gradients in a thunderstorm. The question is: What is the physical mechanism by which those minute droplets get together and form large drops that can be collected as a liquid? In the air-conditioning systems we use in buildings here, they use refrigeration equipment to freeze out the water. This is one of the processes which is being talked about, freezing fresh water out of brackish water. This, however, requires a great deal of energy and is expensive. If you didn't have to go to such low temperatures you could actually carry out this process I am speaking of with very little expenditure of energy, and if you could truly duplicate nature you wouldn't have to put any energy into the system at all. This is long and involved but this is one example of what you might be able to do if you really understood the natural process.

There may be other applications of fundamental knowledge of drop formation. Attempts at rainmaking by seeding clouds with dry ice or other materials have had no success except when the fog droplets have been very highly supercooled; that is, well below freezing temperature. Yet, as everyone knows, raindrops do form in natural clouds under less severe temperature conditions. How does nature do it? We don't know. But if we did know, it might lead to practical methods for the artificial control of rainfall over substantial areas.

Mr. SISK. That is the reason I brought up the subject. I know our chairman is very much interested because of his long work in the Rivers and Harbors Congress. You know we have a saline water program in the Department of the Interior now. Yet, as I understand your statement, you feel we do not have enough basic scientific knowledge to do the job that we are seeking to do in the expenditure of this money.

Dr. FURNAS. That is right.

Mr. SISK. I was interested in such recommendations as would lead people with the scientific minds to come up with these answers and how it might be done. Maybe through this proposal on the National Science Foundation, it might have some bearing. But this to me is a very vital and important, down-to-earth economic problem which we in our country and the world face.

FURTHER REMARKS BY THE CHAIRMAN

Mr. BROOKS. Thank you very much.

At this time the committee will go into executive session for a few further ideas from our distinguished guests.

Let me say before we do go into executive session, that I have listened to a great many hearings in the course of my service in the Congress of the United States, but I don't think there have been any finer presentations at any time to the Congress than we have had here from our distinguished panelists today and those we had prior to this at our first meeting of the panelists.

In that connection, I am reminded that Dr. Russell has a statement he wishes to make before we go into executive session.

THE ECONOMIC RETURN FROM BASIC RESEARCH

Dr. RUSSELL. In connection with the points brought out by Dr. Van Allen, I would like to make a statement which to me is the fundamental argument why the Congress, why any State legislature or public body should support the university.

It is a study which I have made, Mr. Chairman, of your university and mine, Louisiana State. I think I can present these facts very concisely.

It is generally agreed that the value in terms of added earnings through the life of an individual, the value of a degree is on the order of $100,000. This figure is quite commonly accepted. If so, then if we consider that there is a 25-year period during which these earnings are spread, it just happens that in our university there would be a net increase each year of almost $8 million, which happens to be almost precisely our cost of instruction. So that the instructional program pays for itself.

Now, as to the particular study I made, we are familiar with the statement that basic research is the only investment in the world that pays 100 percent annual dividends. I thought I would investigate this from the standpoint of the contribution of our university to the State of Louisiana.

I sent questionnaires, I went through these questionnaires, I studied them very carefully, and was amazed to find out in answer to the question: How many dollars per year are returned to the State, to the citizens of the State by research which we have undertaken?

There is no possible way of figuring that there is less than $100 million per year returned to the State as a result of research in the university.

The total budget of the university is on the order of $26 million. So that in this particular study that I made, the value of basic and reapplied research together is really a 400 percent per year return on investment.

I feel that these figures are very firm. I take full responsibility for them. But to me it is the type of thing we have to drum into our State legislatures; it is the type of thing which I wish this committee to have in its record.

Thank you very much for this opportunity.

Mr. BROOKS. That is a very, very excellent statement, Dr. Russell, which should be placed, I think, immediately after Dr. Van Allen's remarks.

Dr. RUSSELL. Yes.

I wish also to say that I feel certain that a similar study in any other university comes up with the same type of results.

Mr. BROOKS. We are happy to have that statement.

The committee will now go into executive session.

(Whereupon, the committee proceeded into executive session at 11:45 a.m.)

EXECUTIVE SESSION

The meeting convened in executive session at 11:51 a.m., Hon. Overton Brooks presiding.

Mr. BROOKS. Dr. Zucrow has prepared a last minute statement. I understand it is a very fine statement. It properly follows the statement made by Dr. Van Allen and his suggestions. We would be very happy to have it, and then we will have it mimeographed and give it to the press.

Dr. Zucrow.

Dr. ZUCROW. I might say that Dr. Van Allen stole a lot of my thunder. [Laughter.]

STATEMENT BY DR. MAURICE J. ZUCROW

Mr. Chairman, members of the Committee on Science and Astronautics, and members of the Advisory Panel, when I was privileged to address this committee on March 25, 1960, I indicated that whether we like it or not we are committed to a technological race with the U.S.S.R., not only in space but in other fields of science and technology.

The challenge to our technological supremacy should not be taken too lightly or we may find ourselves lagging behind the U.S.S.R. in other scientific fields as we now lag somewhat behind them in space flight.

Dr. R. J. Russell in an excellent paper pointed out that we lag behind the U.S.S.R. in a planned approach to determining the constitutional and physical characteristics of the Earth, and he made some suggestions for strengthening our scientific position in the Earth sciences.

Dr. Revelle discussed the importance of more research effort in the field of seismology, so that methods can be developed for detecting underground explosions. He also pointed out that a change is occurring in the planning of scientific developments in the U.S.S.R., and Dr. Noyes substantiated this.

The crisis in university support

The change is to the system which until a few years ago was predominant in the United States, that is, giving much more support to the universities in conducting research through enhanced support of graduate study.

It is with the latter subject that I wish to deal today. If we expect to expand our activities in science and technology, then we are

confronted with a major educational problem. I will confine my comments to engineering education, since I have some knowledge in that area.

With the advances in scientific knowledge and technology which the future will bring, there will be a great need for engineers who have the basic education in science and the humanities, and who also are equipped with not only the ability of solving new problems as they arise, but also have the imagination for conceiving new applications for existing and new knowledge.

Although the education of the engineer will be somewhat similar to that of a scientist, being based on the sciences and humanities, its objectives are quite different. The educational program of the engineer must be directed to equip him so he will have a capability of applying scientific knowledge and engineering judgment, not only to solving practical problems, but also to developing the new knowledge required for solving those practical problems.

Need for graduate training in engineering

It does not appear possible to me that the necessary fundamental education of the type of engineer which will be needed for dealing with the very complex problems of the future, such as those outlined by my good friend, Dr. Furnas, can be accomplished in a 4-year educational program.

His education will have to be much more extensive. Consequently there must be an expansion of effort in the field of graduate study for those who are to be the future engineering leaders, and every effort must be made to attract and make it possible for top engineering graduates to embark upon programs of graduate study.

Experience has demonstrated that research must be an integral part of a graduate study program. Through research the student learns the true significance of the scientific method, develops his confidence and judgment, and in addition contributes to new scientific or engineering information.

The national problem is what must be done to develop the needed type and number of engineers that are required for assuring that the United States has the scientific and technological capabilities for insuring its world leadership in science and astronautics.

To achieve that goal it is essential therefore that there be an adequate support of research and graduate study in our engineering schools and universities.

Since Dr. Van Allen has presented a written statement in which he discusses this need in detail, I submit this part of my statement as an endorsement of the general ideas contained in his statement.

In closing, I wish to point out that Dr. Noyes made some interesting comments on the educational system in the U.S.S.R., and corroborated Dr. Revelle's statement of the increasing cooperation of research institutes in the U.S.S.R. with the universities, which is indeed the system upon which the scientific and technological developments of this country were founded.

Mr. BROOKS. Thank you very much, Dr. Zucrow.

Any questions?

I will say this. I will throw the meeting open to questions by anyone or observations by anyone, either the panel or the members of the committee.

Dr. Noyes?

PLACE OF THE SMALL COLLEGE

Dr. NOYES. I would like to return to this question of the small college, because it concerns me.

Both Dr. Van Allen and I are graduates of small colleges in Iowa, which I believe are rivals in football from time to time.

I think we would both agree, and I am sure most people would agree, that the small college properly run and well staffed is a very important part of our educational system.

I think, however, the 2,000 small colleges may be too many. I doubt if we can at the moment get good teachers for these 2,000, can finance them with the kind of instructional laboratories which they need, and I believe, also, statistics show that while many of our graduates come from these institutions they don't come from a very large fraction of the 2,000. They may come from a couple of hundred or thereabouts.

So I again would like to return to my statement that, while I would not for a moment do away with the small college, I would put my efforts on the good ones; I wouldn't support all 2,000.

Here you run into a real political problem, where the fellow at the crossroads thinks his college is just as good as the one at the next crossroads, and how are you going to decide which one you give the money to? This I will leave to Congress. It is not my problem.

Mr. BROOKS. Any further observations on that point or any other point?

(No response.)

Mr. BROOKS. Any further questions?

As I understand, there were a good many things that some of the members of the panel, especially, wanted to mention to the committee in an off-the-record discussion or executive sessions, whichever you prefer.

Mr. Goland—President Goland?

FURTHER REMARKS OF MR. GOLAND

Mr. GOLAND. Mr. Chairman, will this be for the record, sir?

Mr. BROOKS. Either way you want it.

Mr. GOLAND. I prefer it be off the record.

Mr. BROOKS. I will ask the reporter to stop taking it there. He will be glad to do it.

Off the record.

(Discussion off the record.)

Mr. BROOKS. Thank you very much for your statement.

Dr. Furnas made a statement and he more or less approaches problems from the standpoint of purely basic research.

President Goland, of the Southwest Research Institute at Texas, made a statement in the last panel discussion that we had which approached, certainly, the oil and gas industry—and I am from the Southwest—in a little different manner.

His approach was, as I recall, the perfection of, perhaps, applied science. That is the increasing of the yield from our oil and gas resources, and perhaps coal, too; whereas Dr. Furnas approaches the problem from the viewpoint of pure basic research, and that is producing a yield where there is no yield at the present time.

Isn't that right? One is a little bit more encouraging to us in the Southwest than the other is.

Mr. GOLAND. Mr. Chairman, I would really be biting the hand that taught me if I concur with you completely. [Laughter.]

I am a very old student of Dr. Furnas, not at a university, but he was my boss at the Cornell Aeronautical Laboratory. I am a very great admirer of his.

While what you say is correct, I think Dr. Furnas and I have less difference of opinion than might appear on the surface. Even in such things as increasing petroleum production, the trick is to learn enough on the basic level so that you can move into a new producing field, and without a great deal of cut and try, know how to produce in the best manner.

I think Dr. Furnas' point is, simply, that once we know more about the basic processes, we can rapidly translate those into applied accomplishment. With this I entirely agree.

Incidentally, I though Dr. Furnas would also mention an even more spectacular illustration—marginal recovery in the sea. It is the fact that in certain areas of the Pacific, as well as other areas of the ocean, the bottom is covered with metallic nodules of high manganese concentration. How are these nodules formed? We really don't know what has caused them to come into being. Yet, whole areas of the ocean are covered with them. Large quantities of this critical material are there for the taking, if we just had a system by which they could be brought to the surface.

FURTHER REMARKS OF DR. RUSSELL

Dr. RUSSELL. Off the record, Mr. Chairman?

Mr. BROOKS. Yes.

(Discussion off the record.)

Mr. BROOKS. Any further comment?

SALARIES OF SCIENCE ADMINISTRATORS IN GOVERNMENT

Dr. NOYES. May I make just one? It is a very highly specific one that may be totally inappropriate, but I believe the National Bureau of Standards is under the purview of this committee, is that right?

Mr. BROOKS. That is right.

Dr. NOYES. I don't know whether in the appropriation act of that agency the salary of the Director has been raised or not. I am not speaking now of a plea for an individual.

Mr. BROOKS. I may say this, that we did embody in one of our bills a provision to raise his salary. In my judgment, it should be raised. We encountered some opposition on the floor there, and we had to strike it out in order to save the bill.

Dr. NOYES. I am not putting up a plea for Dr. Astin, although I personally think he is a fine man, but that salary of his puts a ceiling

on those of his Associate Directors, because nobody can be paid more than he is.

This is the only reason I am mentioning this to you.

Dr. RUSSELL. National Science has that same difficulty. Waterman's salary puts the ceiling on everyone else's.

Mr. BROOKS. That is the one I am talking about, Dr. Waterman's salary. We did provide in one of the bills for it. And it should be done, too. It should be a level at what others are with the same responsibilities.

We had to take that out in order to save the bill. The members of the committee will recall that. We will undoubtedly in time rectify that inequity.

Any further comment?

(No response.)

CONCLUDING REMARKS BY THE CHAIRMAN

Mr. BROOKS. If not, I want to personally and on behalf of the members of the committee thank you gentlemen for coming here to this panel discussion.

I think we have gotten a great deal out of it, and I think it has been most helpful and will in the future be even more helpful to the deliberations of our committee in approaching the problems that we have.

Again I remind you that we have a relatively new committee, it is the newest committee in the U.S. Congress, and yet it is a basic committee, it is a major committee, and I think we have unlimited opportunities before the committee.

The question is purely a matter of time in getting around to all of these problems. You have helped us a great deal. We would like to feel that in the future as we go along, if something comes up we may have the opportunity of addressing a letter or a communication to you, getting your views on a specific matter.

In that event, we will treat the views as executive, off the record, or just whatever way you wish it done. We don't want to embarrass anybody. This committee is not going to embarrass anybody at all.

At the same time, sometimes the prestige of a declaration of some member of the panel, some great educator, would help legislation a great deal. In that event, you would be aware beforehand of the fact that we intended to use it that way.

So, again, I want to thank you.

This afternoon you will still have the opportunity of the committee room here for any discussions with any of the members of the committee to whom you may see fit to talk.

On the floor this afternoon, there is a 2-hour discussion on our bill amending the NASA Act. I will put in a good deal of time, myself, there, because I want to see the way in which the discussion trends. So if there is no further business, the panel will stand adjourned until further notice.

In the meantime, anyone who wishes to go to the House or the Senate, Dr. Sheldon, will you provide them with passes. There are an ample number of passes available in my office or elsewhere.

The committee stands adjourned. We thank everybody.

(Whereupon, at 12:36 p.m., the meeting was adjourned.)

Informal Sessions With the Panel

Following the formal sessions of the panel with the committee on June 2, which ran from 10 a.m. until 12:06 p.m., the members of the panel listed below continued discussions on an informal basis with Dr. Charles S. Sheldon II, technical director, Spencer M. Beresford, special counsel, and Dr. Edward Wenk, Jr., senior specialist in science and technology, Library of Congress: Dr. Edward J. Baldes, Martin Goland, Dr. W. Albert Noyes, Jr., Dr. Roger Revelle, Dr. James A. Van Allen, Dr. Fred L. Whipple, and Dr. Maurice J. Zucrow. Other panel members met with individual members of the committee. Some of the discussions begun at noon continued until 9:30 p.m., and although no attempt was made to keep minutes, many useful exchanges of ideas occurred.

Again on June 3, following the formal session open to the public between 10 a.m. and 11:45 a.m., and the executive session, from 11:51 until 12:36 p.m., members of the panel listed below continued discussions among themselves and with Dr. Sheldon until 3:30 p.m.: Dr. Baldes, Dr. Furnas, Mr. Goland, Dr. Malone, Dr. Noyes, Dr. Whipple, and Dr. Zucrow. Other panel members met with individual members of the committee. During the afternoon, some of the panel went to the House gallery to hear debate on the patent provisions of the Space Act of 1958, amendments to which were being offered under a bill reported by this committee.

Letters of Acknowledgment to Panel From Chairman

The first of the letters given below was addressed to each of the 10 panel members attending the second session; the second letter was addressed to each of the 4 members unable to attend (omitting only individual comments appropriate to the reasons in each specific case):

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C., June 6, 1960.

Dear ——— ———: This is to express my very warm personal thanks and the sincere appreciation of the committee for your participation in the June meeting of the Panel on Science and Technology. Other members of the committee have told me they viewed the meeting as very successful, giving them many new ideas which they can use in the future.

My only regret about our meeting was that it had to come in the closing days of this session when all of us here are really pushed for time, and it is a tribute to the seriousness with which the members view your contribution that we had such fine attendance during the actual meeting hours both mornings. We know your coming at this time of year involved sacrifice, too.

It is my hope that we can schedule the next round of formal meetings in January next year when pressures on time will be less, and we can look forward to a combination of business meetings and some social gathering with participation by the panel, the committee, and

high officials of both the legislative and executive branches of the Government.

With warm personal regards.

Sincerely,

OVERTON BROOKS, *Chairman.*

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., June 6, 1960.

DEAR ——— ———: We have concluded our June meetings of the Panel on Science and Technology with very successful and gratifying results. Ten members of the panel were able to come, even though this is a very busy season for both members of the panel and for Congress. When the proceedings are in print, I shall forward a copy to you.

I know that your absence was made necessary by a compelling reason and that we are unlikely to find any week in the year which will fit the needs of every individual member of the panel. Of course, I hope very much that when we have a formal session again in January, it will be possible for you to come. We look forward to a good program of business, and probably some social occasion, too, which will be shared by the panel, the committee, and by high officials of both the legislative and executive branches of Government.

With warm personal regards.

Sincerely,

OVERTON BROOKS, *Chairman.*

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